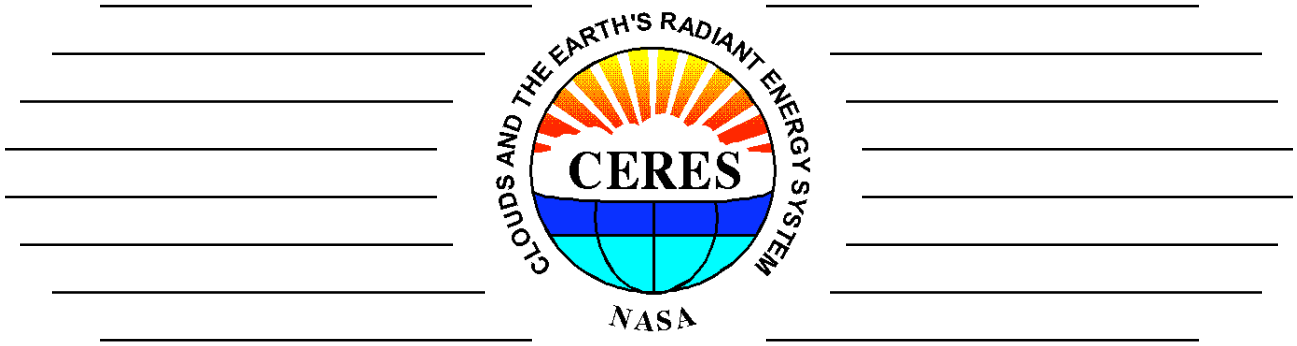
Terra/Aqua Instrument Calibration Report Edition 3 Status



Kory J. Priestley
Susan Thomas, Denise Cooper,
Phil Hess, Grant Matthews, Peter Szewczyk,
Dale Walikainen, Robert Wilson

CERES Science Team Meeting
Victoria, Canada
November 14, 2007

NASA Langley Research Center
Atmospheric SCIENCES

CERES Instrument Working Group Homepage

http://asd-www.larc.nasa.gov/Instrument

Agenda

- Instrument Working Group Status

- Instrument Operational Status

- Discussion of preliminary Edition3 results

  - Special focus on SW results

-Note: Titles Edition3P, Edition3_Test, Beta9 and Beta7 are used interchangeably throughout presentation

Instrument Working Group Status

- **Personnel: Grant Matthews has left CERES and begun working with Doreen Neil**

- **Transitioned responsibilities to other individuals in the group (I.e. Dale Walikaenan and Peter Szewczyk)**

    - ***Conducted an independent review of codes***

    - ***Migrating these codes to Unix environment***

- **Developing independent validation of model results (Susan Thomas, Peter Szewczyk)**

- **Enlisted the help of Costy Loukachine to support analysis of preliminary Edition3 results.**

- ***Significant resources expended supporting engineering trade studies to manifest FM-5 on the NPP spacecraft.***

CERES Terra/Aqua Health & Status

With the exception of the SW channel on the CERES/Aqua FM-4 Instrument, the CERES Terra/Aqua instruments are functioning nominally…

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	92 +
Aqua	FM3, FM4	5/02	6/02	65 +
NPP, SmallSat	FM5	***9/09, 10/10***	-	-

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NPP, SmallSat	FM5	***9/09, 10/10***	-	-

27 + Instrument Years of Data

Radiometric Performance Requirements

CERES is defined as a class 'B' Mission
5-year design Lifetime

Spectral Regions	Solar		Terrestrial		Atmospheric Window
Wavelengths	0.3 - 5.0 μm		5.0 - 200 μm		8 - 12 μm
Scene levels	<100 w/m^2-sr	>100 w/m^2-sr	<100 w/m^2-sr	>100 w/m^2-sr	All Levels
Accuracy Requirements	0.8 w/m^2-sr	1.0 %	0.8 w/m^2-sr	0.5 %	0.3 w/m^2-sr
Stability Requirements		< 0.14%/yr		< 0.1%/yr	
Climate Stability Goals		< 0.6 w/m^2/dec < 0.03 %/yr		< 0.2 w/m^2/dec < 0.02%/yr	

- **Requirements for CERES are more stringent than ERBE's by a factor of 2**
- **Requirements per Ohring et. al. are more stringent than CERES by a factor of 3-5**

Instrument Artifact Removal Strategy

Remote sensing instruments generally exhibit time varying artifacts in their data products. For CERES these artifacts stem predominantly from either of 2 physical entities…..

- **Radiometric Gain Change**
  - **Wavelength independent change in sensor responsivity**
  - **Corrections implemented in Count Conversion algorithm (SS1)**
- **Spectral Response Change**
  - **Wavelength dependent change in sensor optics**
  - **Corrections implemented in Spectral Unfiltering algorithms (SS2)**

Radiometric Channel	Spectral Region	
	SW	LW
Total	<3.0 um	>3.0 um
SW	<5.0 um	-
WN	-	8-12 um

BDS and ERBE-Like Release Strategy

Edition1_CV - Static Algorithms and coefficients - baseline product used cal/val protocol

Edition2 - Temporally varying coefficients to correct for traceable radiometric drift. All spectral changes are broadband and 'gray'.

Edition3 - *Delivery date Spring 2008*. Incorporate temporally varying spectral artifacts in the SW measurements. Re-analysis of Ground Calibration with additional component characterization measurements.

User Applied Revisions - Advance capabilities to the users prior to the release of the next Edition.

Edition2 products lag Edition1 by minimum of 6 months

Why are CERES Edition2 radiances not perfect?

A question of time scales, experience and balancing accuracy with providing data products to the community.

- **Edition2 Radiances have been released on ~6 month centers**
- **6 months is just a blink of an eye when analyzing long term trends…**

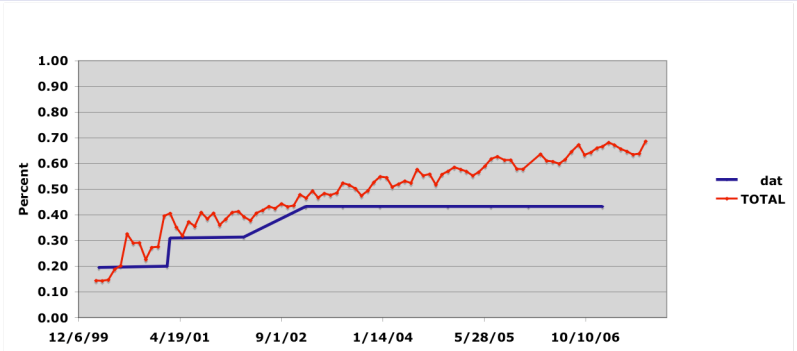
Same time scale as phenomena which influence instrument response

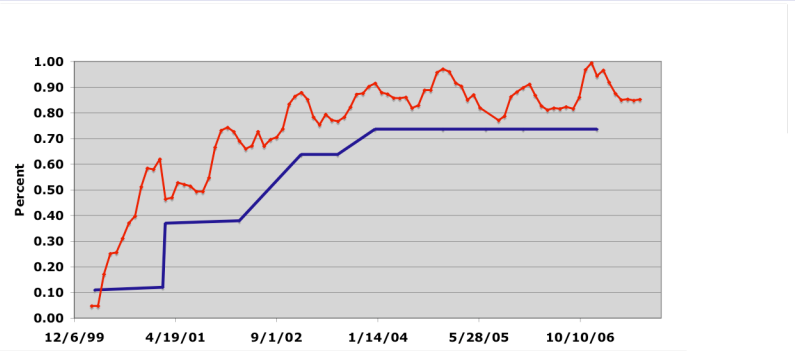
- **Beta Angle**
- **Earth Sun Distance**
- **Orbital shifts**
- **Instrument Operational modes (I.e RAPS vs. Xtrack)**

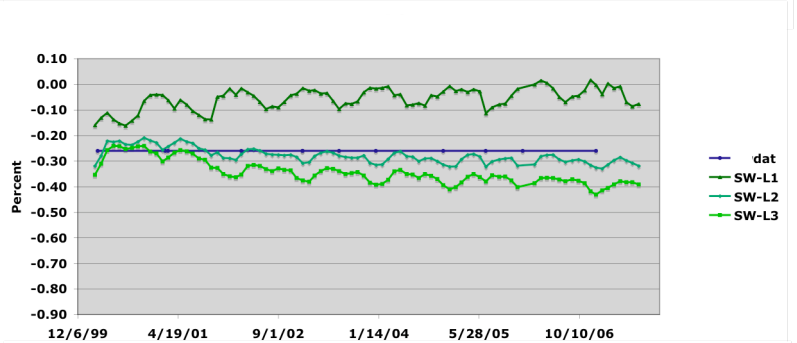
Complicates separation of instrument 'artifacts' from natural variability.

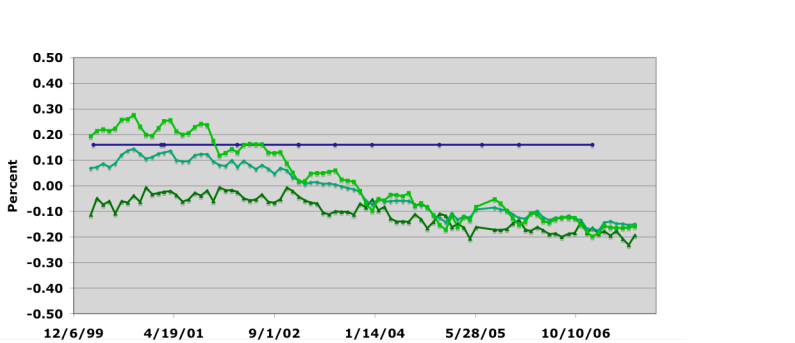
Edition3 reprocessing of the first 5 years of CERES radiances allows a much more rigorous identification and separation of instrument artifacts and true climate signals.

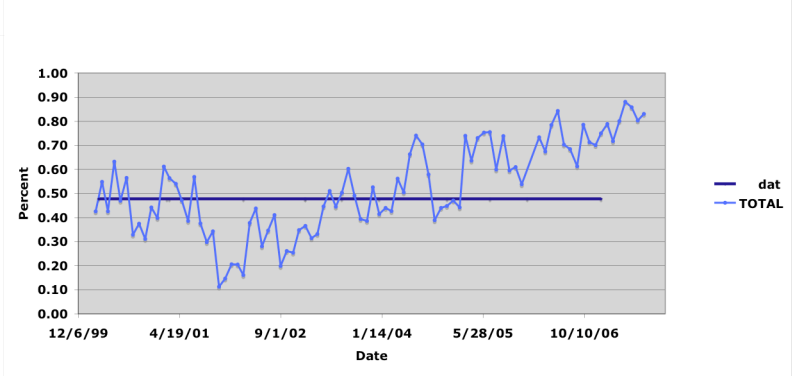
Terra Monthly Average ICM Results

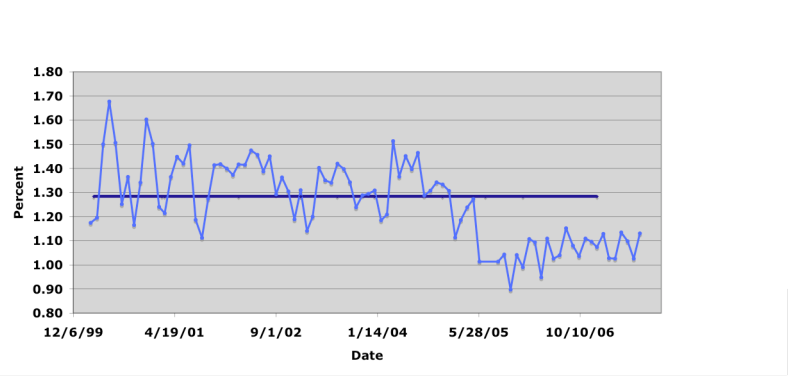






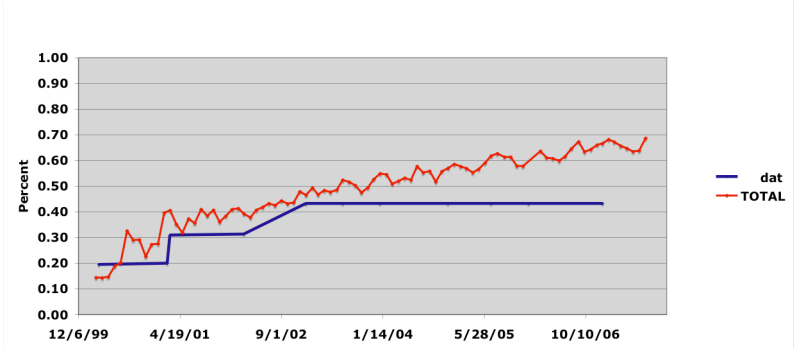


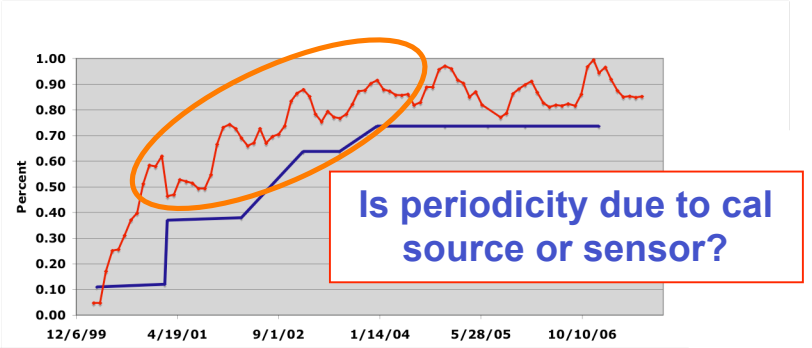




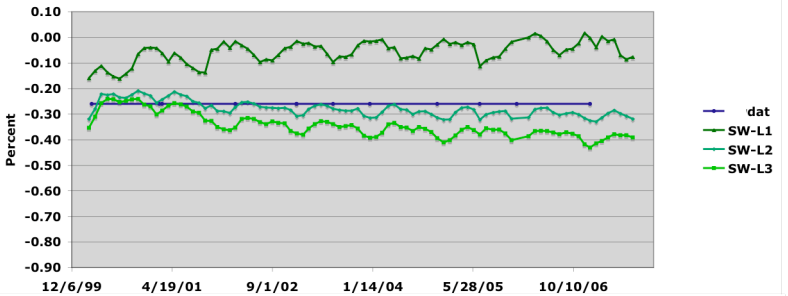
FM1 **FM2**

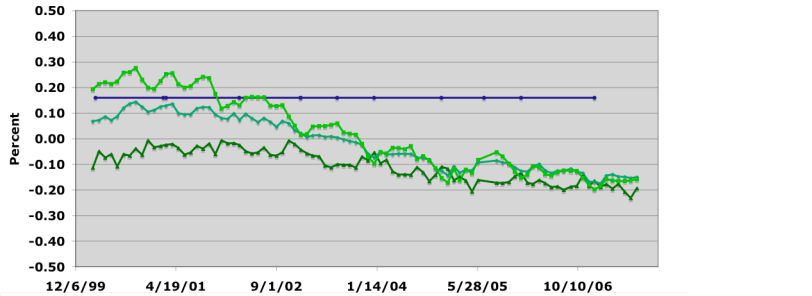
Terra Monthly Average ICM Results

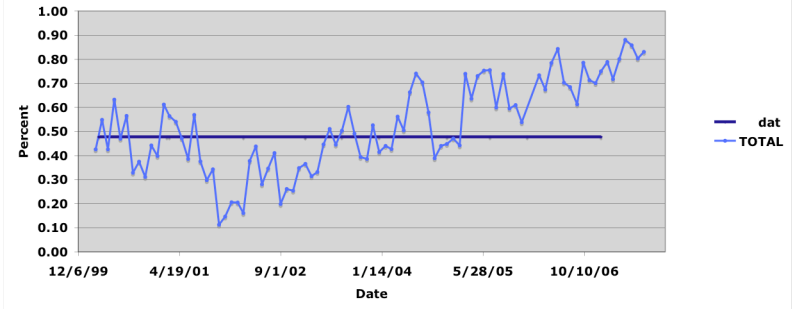


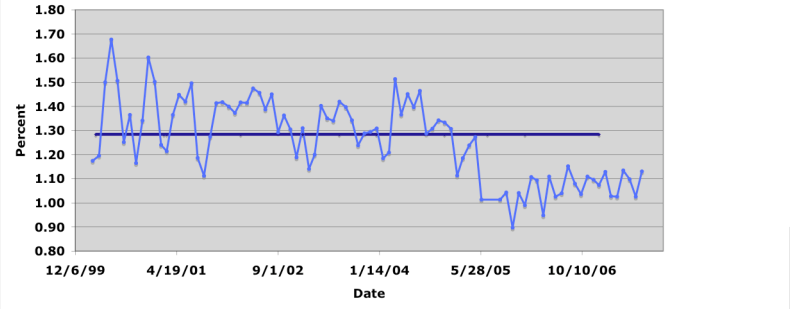


Is periodicity due to cal source or sensor?



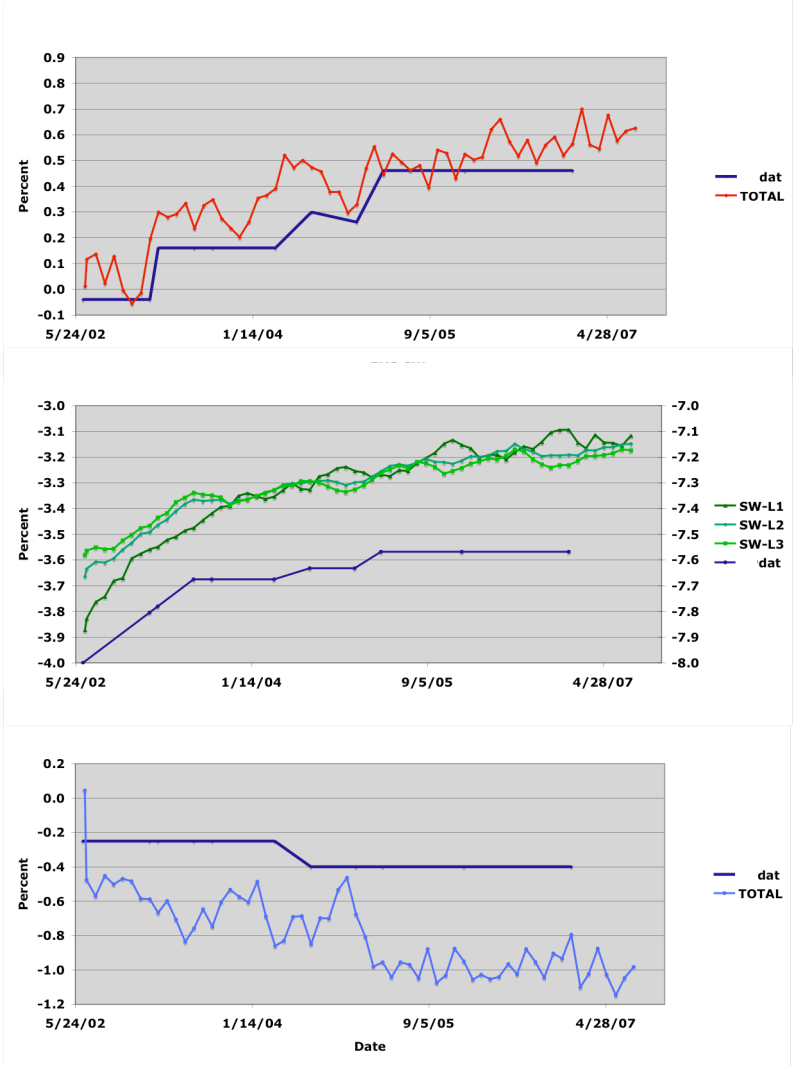


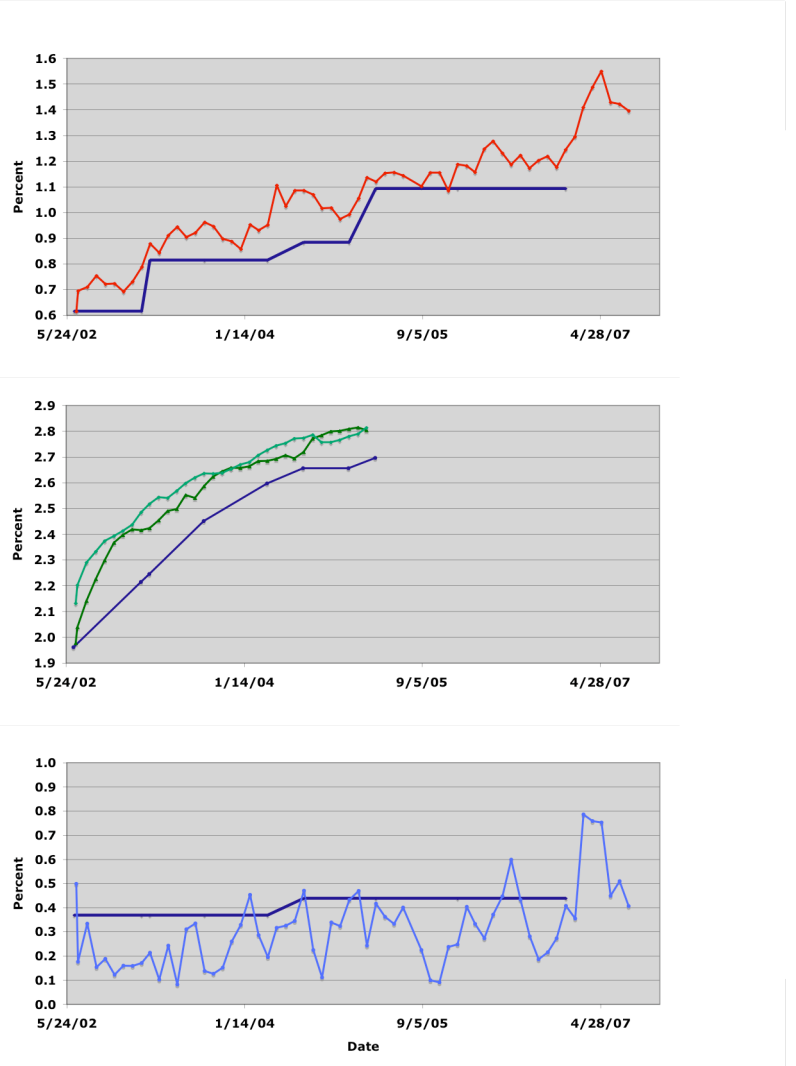




FM1 **FM2**

Aqua Monthly Average ICM Results





FM3 **FM4**

CERES BDS and ERBE-Like Product Status

Spacecraft	Product	Version	Available	Months Processed
TRMM	BDS	Edition1	Yes	1/98 - 8/98 , 3/00
	ERBE-Like	Edition1	Yes	1/98 - 8/98 , 3/00
		Edition2	Yes	1/98 - 8/98 , 3/00
Terra	BDS	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 12/06
	ERBE-like	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 12/06
Aqua	BDS	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 12/06
	ERBE-like	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 12/06

Note: Red text indicates months are in production and may not currently be publicly available

CERES Unfiltered Radiance Summary

•Cal/Val Protocol demonstrates radiometric stability of the data products through 12/2006 of….

	Edition1				Edition2				Edition2_Rev1				Edition 3 (Anticipated)			
	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4
LW_{day}	.3	.6	.4	.4	.125	.125	.3	.3	.125	.125	.15	.15	<.1	<.1	<.1	<.1
LW_{night}	.1	.125	.125	.125	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	<.1	<.1
SW	.2	.4	.4	.5	.2	.3	.3	.4	<.1	<.1	.25	.25	<.1	<.1	<.1	<.1
WN	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	<.1	<.1

Note: **Values apply to all-sky global averages**
Units are in %/yr

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LW_{day}	.3	.6	.4	.4	.125	.125	.3	.3	.125	.125	.15	.15	<.1	<.1	<.1	<.1
LW_{night}	.1	.125	.125	.125	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	<.1	<.1
SW	.2	.4	.4	.5	.2	.3	.3	.4	<.1	<.1	.25	.25	<.1	<.1	<.1	<.1
WN	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	<.1	<.1

Note: **Values apply to all-sky global averages**
Units are in %/yr

SW Edition 3P Calibration

Model Derived Gains and Spectral Response

SW Edition 3P Calibration

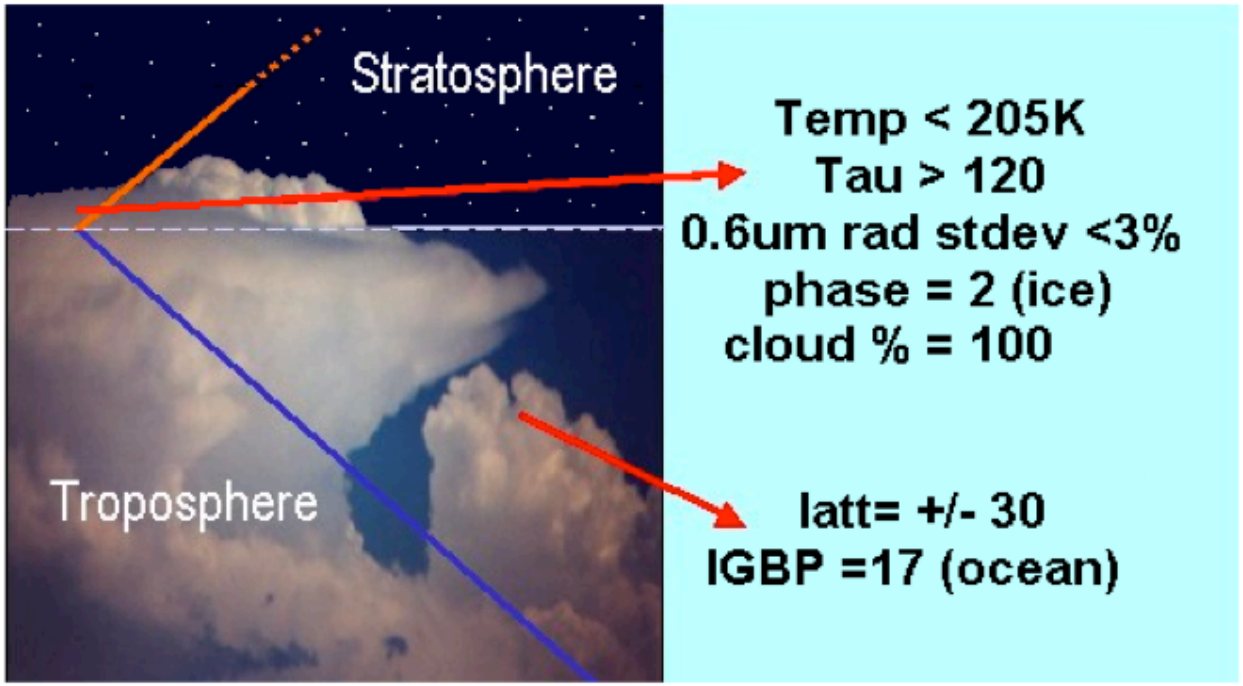
Edition2Rev1 adjustments assumed no significant spectral degradation while operating in the cross-track mode. Edition3 is not bound by this assumption and thus requires new validation criteria/constraints.

The Rev1 SW corrections were optimized for clear ocean, and global all-sky measurements. Edition 3 will implicitly correct all scene types as we are not assuming 'Gray' changes.

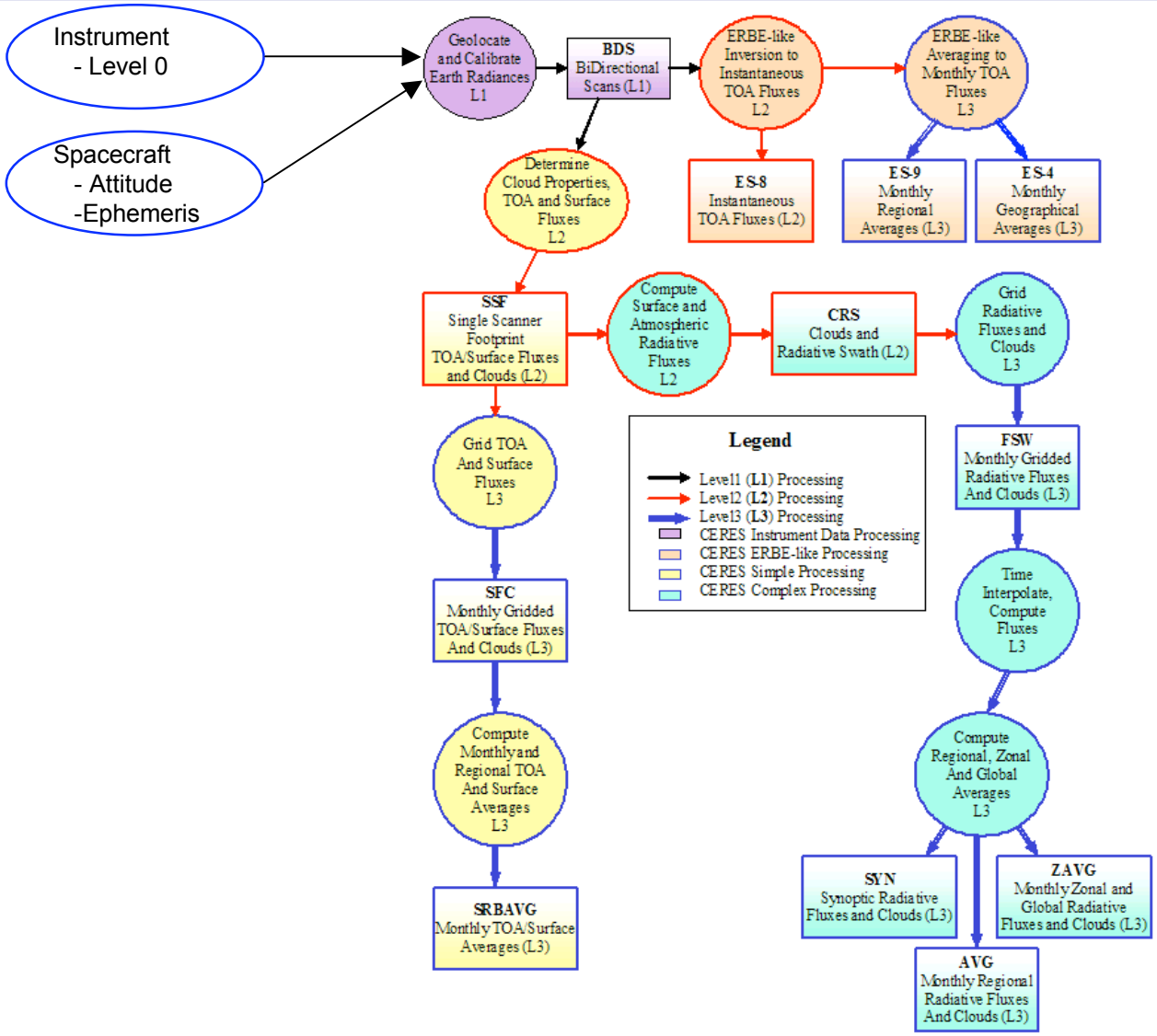
- **Incorporation of improved Scence ID from SSF product:** Increases value of vicarios validation studies developed for the Edition2 Cal/Val protocol.
- **Deep Convective Cloud Albedo**: Calculate the albedo of the coldest, brightest and most uniform clouds in the tropics. These measurements then replace the MAM solar calibrations.
- **Direct comparison of nadir data**: Constrain contamination/UV exposure model to optimize match of nadir footprints between two instruments on the same platform. Use of clear ocean and allsky scenes allows the model to determine coloration of spectral response changes.

Deep Convective Cloud Definition

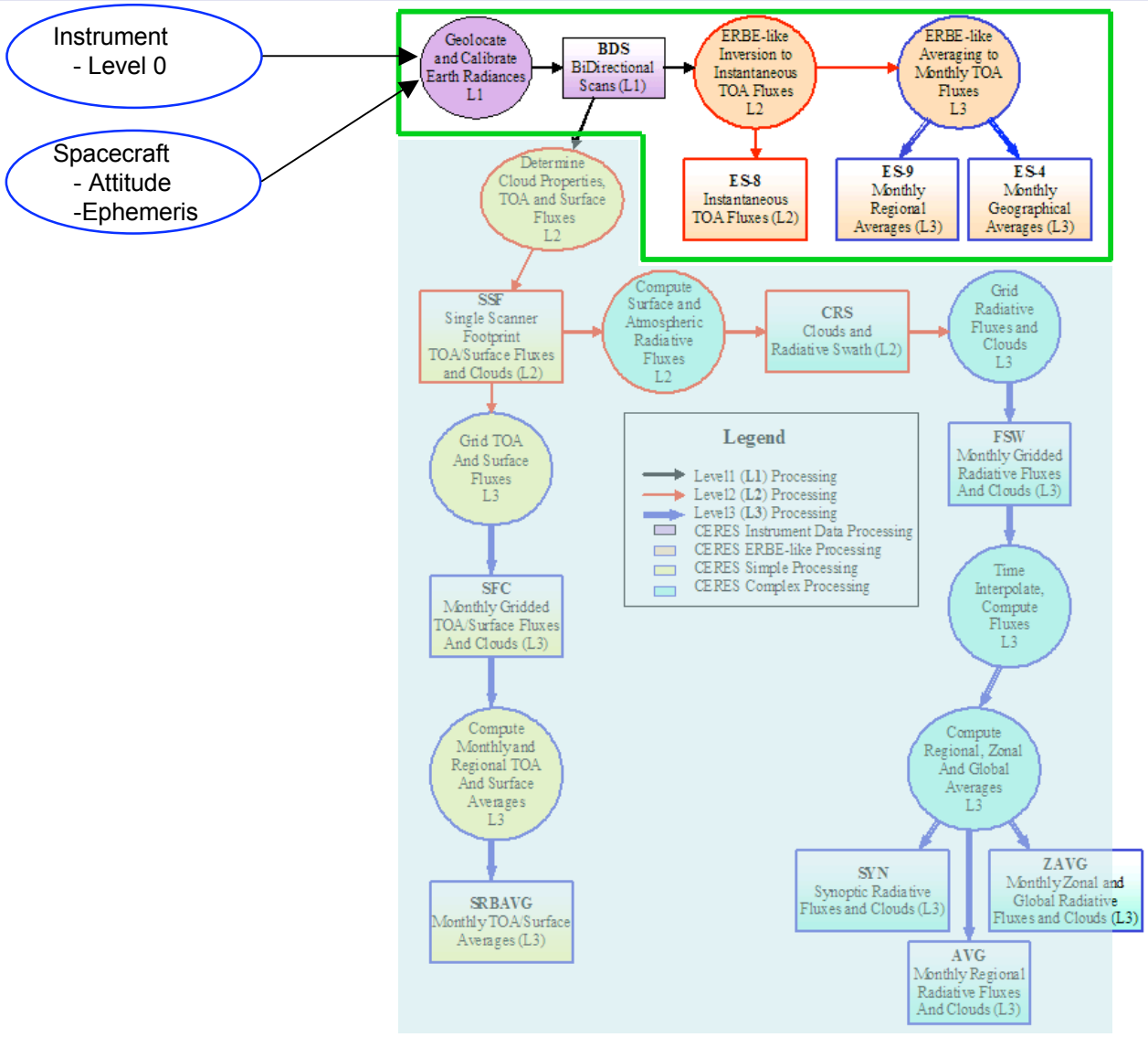
Use MODIS to find SW footprints of thickest, coldest and most uniform tropical ocean Deep Convective Clouds



CERES Data Flow Diagram



Edition 2 Inputs for Cal Val Protocol



ERBE-Like

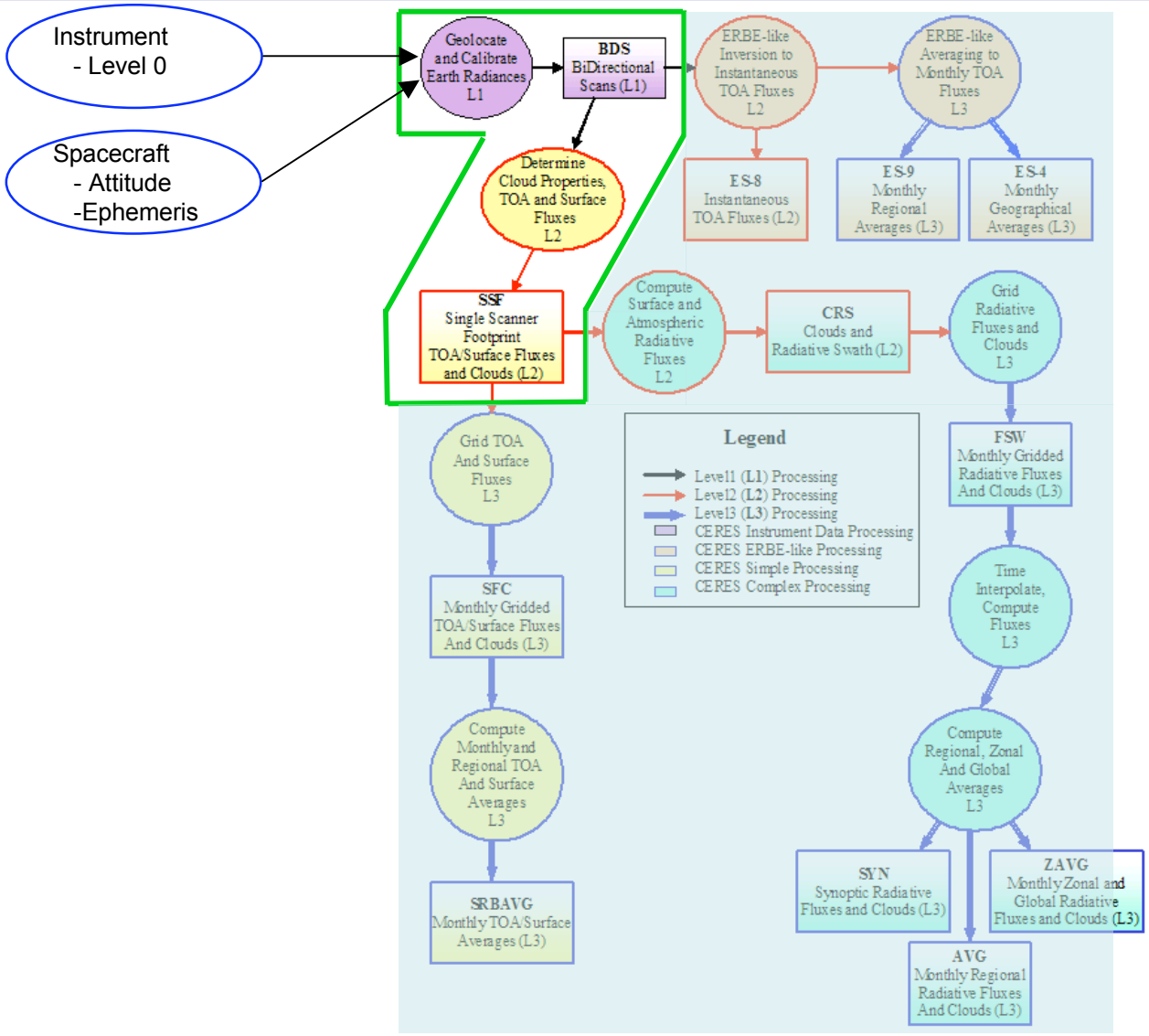
Advantages

- Availability
- Small Data Volume

Disadvantages

- Inadequate Scene ID

Edition 3 Inputs for Cal Val Protocol



SSF

Advantages

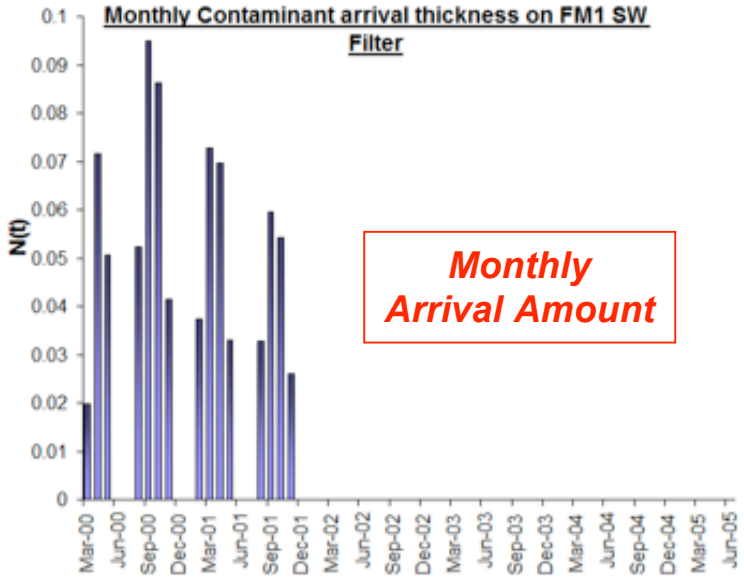
- Full CERES Algorithms
- Improved Scene ID

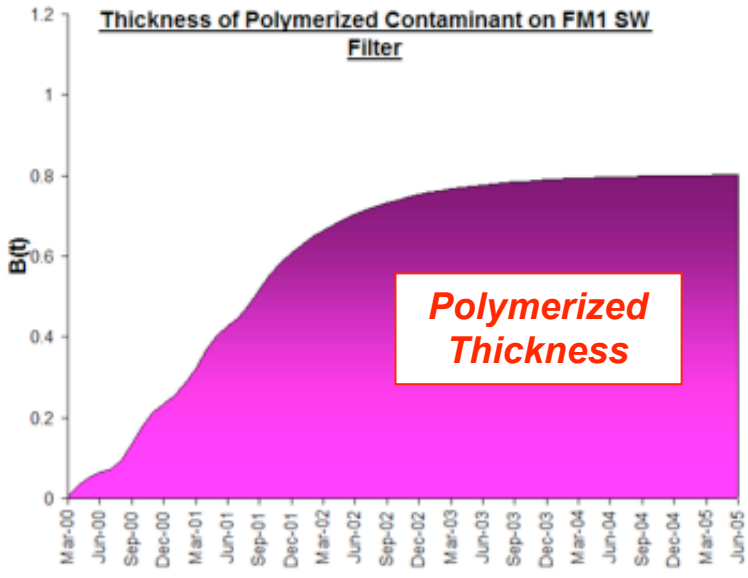
Disadvantages

- Availability
- Large Data Volume

Contaminant Arrival and Polymerization

Edition3P
FM1 Contaminant Thickness
Estimated by model





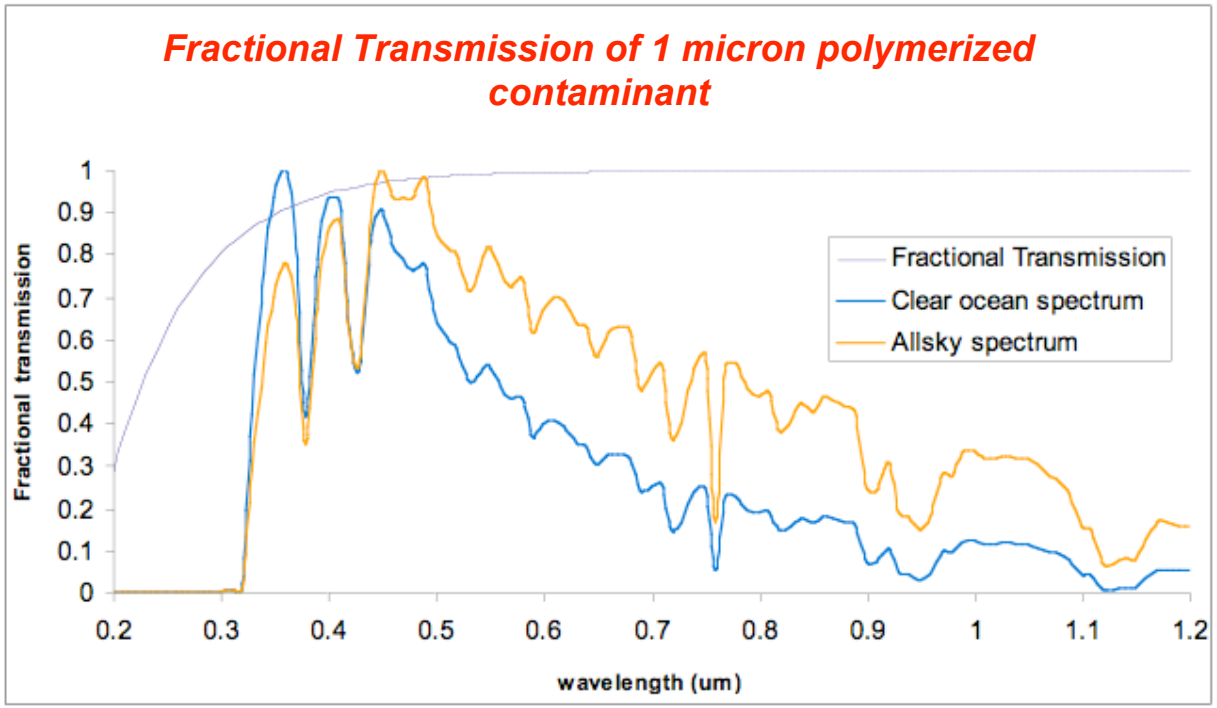
$$\frac{dB(t)}{dt} = \rho \left[\int_0^t N(\xi) d\xi - B(t) \right] + \beta . N(t)$$

Sample Spectral Degradation

Currently the model assumes contaminants can only cause a *decrease* in throughput.

$$D(\lambda) = [1 - M.e^{-\alpha\lambda}]$$

Fractional Transmission of 1 micron polymerized contaminant



Quartz Degradation Mechanisms

Charged Particle Impingement

- Proton, electron impingement mission lifetime duration

Molecular Contamination

- Thin film builds due to material outgassing
- typically decays with time
- Surface Residence Time is a function of temperature
- Build-up requires Deposition Rate > Departure Rate
- UV Exposure enhances accumulation

Particulate Contamination

- Dust, predominantly pre-launch, launch

Photochemically Enhanced Deposition

UV Light can cause contamination to condense on surfaces that would otherwise remain clean

Presumably, the UV light initiates a polymerization process that either:

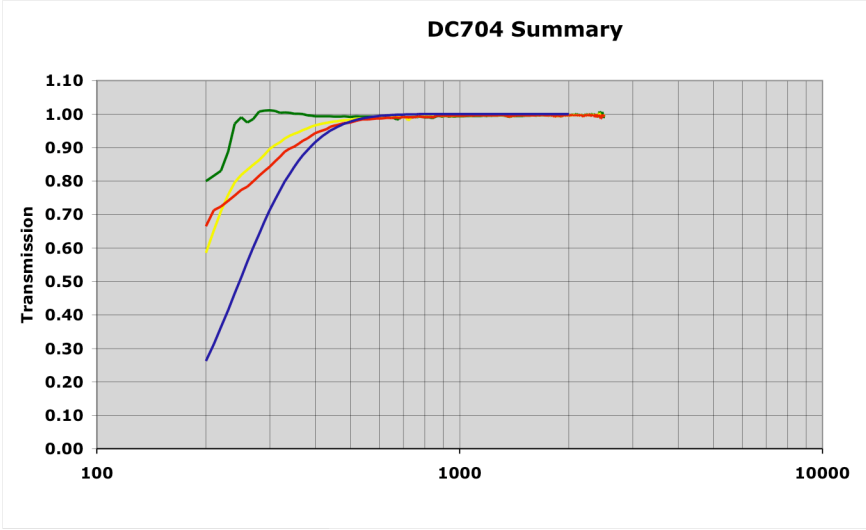
1) Binds the contaminant molecule to the surface,

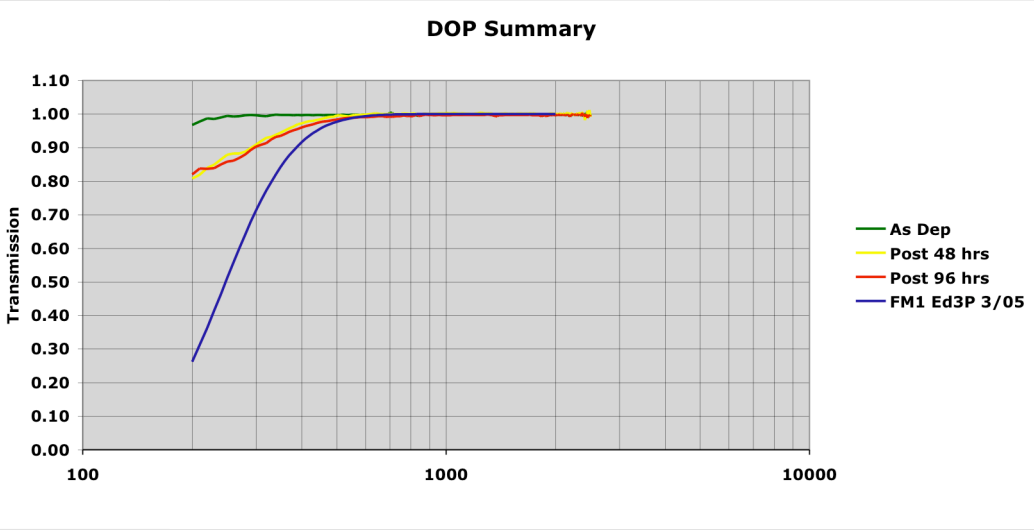
2) Binds several contaminant molecules into larger molecules with a correspondingly longer residence time.

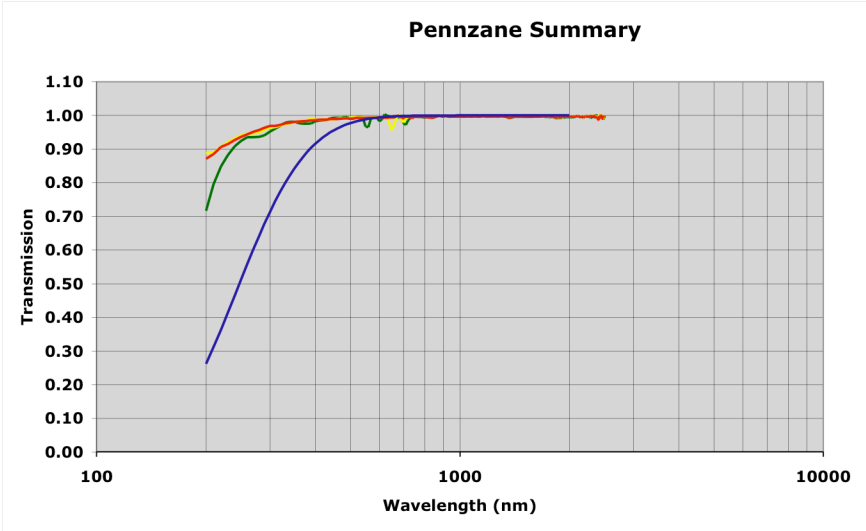
Even warm surfaces may be subject to the deposition of contaminant layers if they are exposed to solar UV

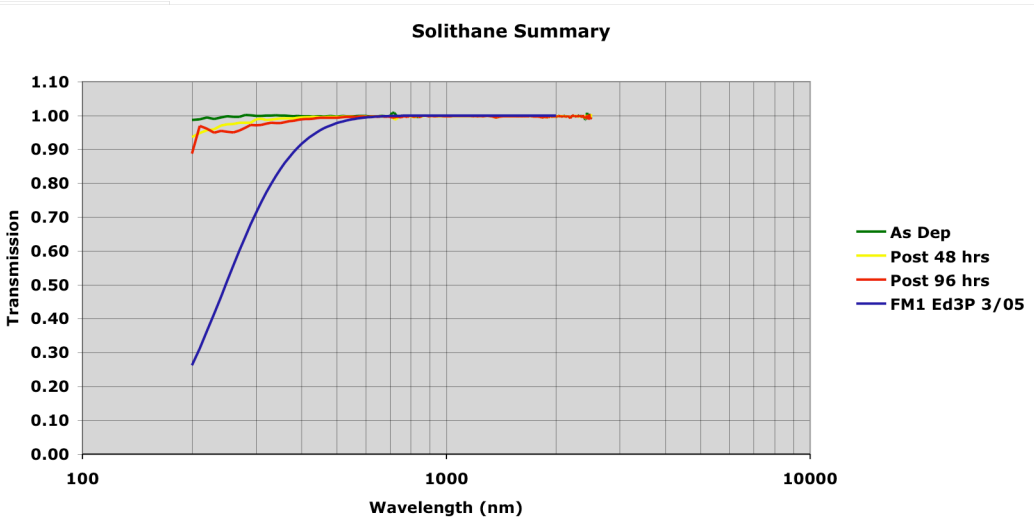
Rate of photochemical deposition of contaminants is seen to increase as the molecular arrival rate decreases. *i.e. sticking coefficient increases*.

Preliminary Results of NGST Contamination Study

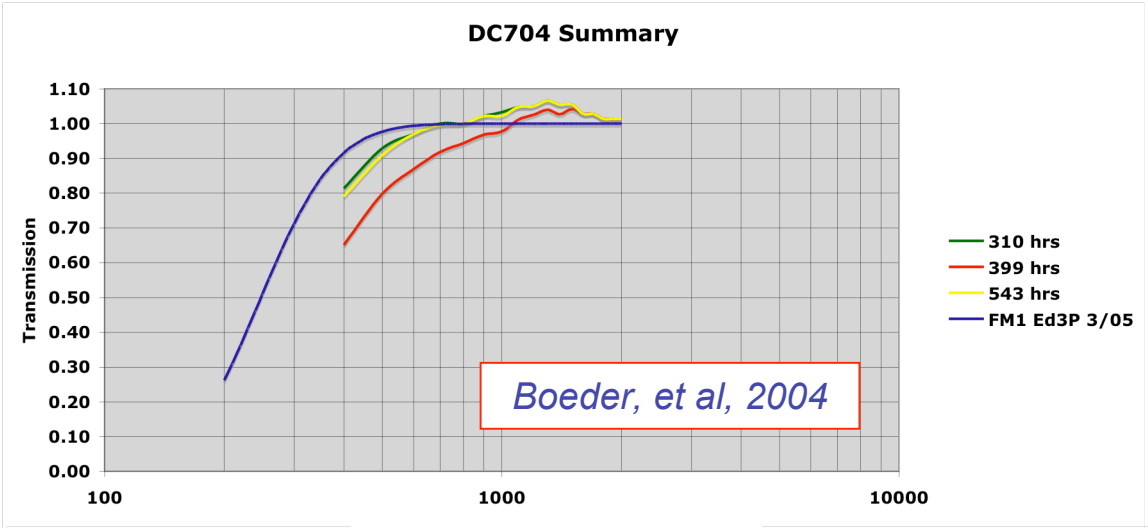


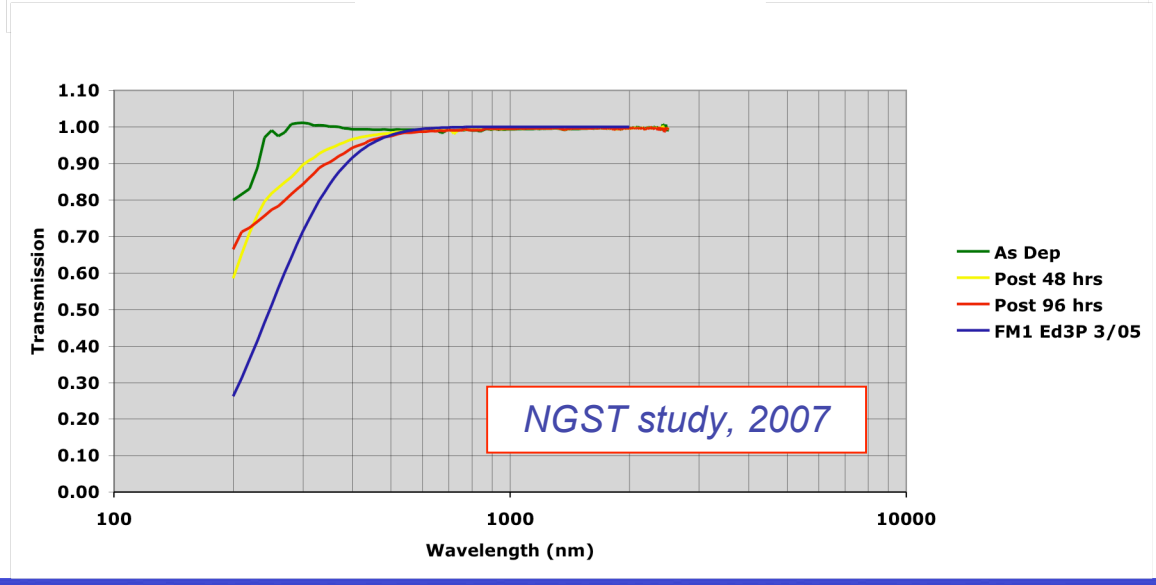






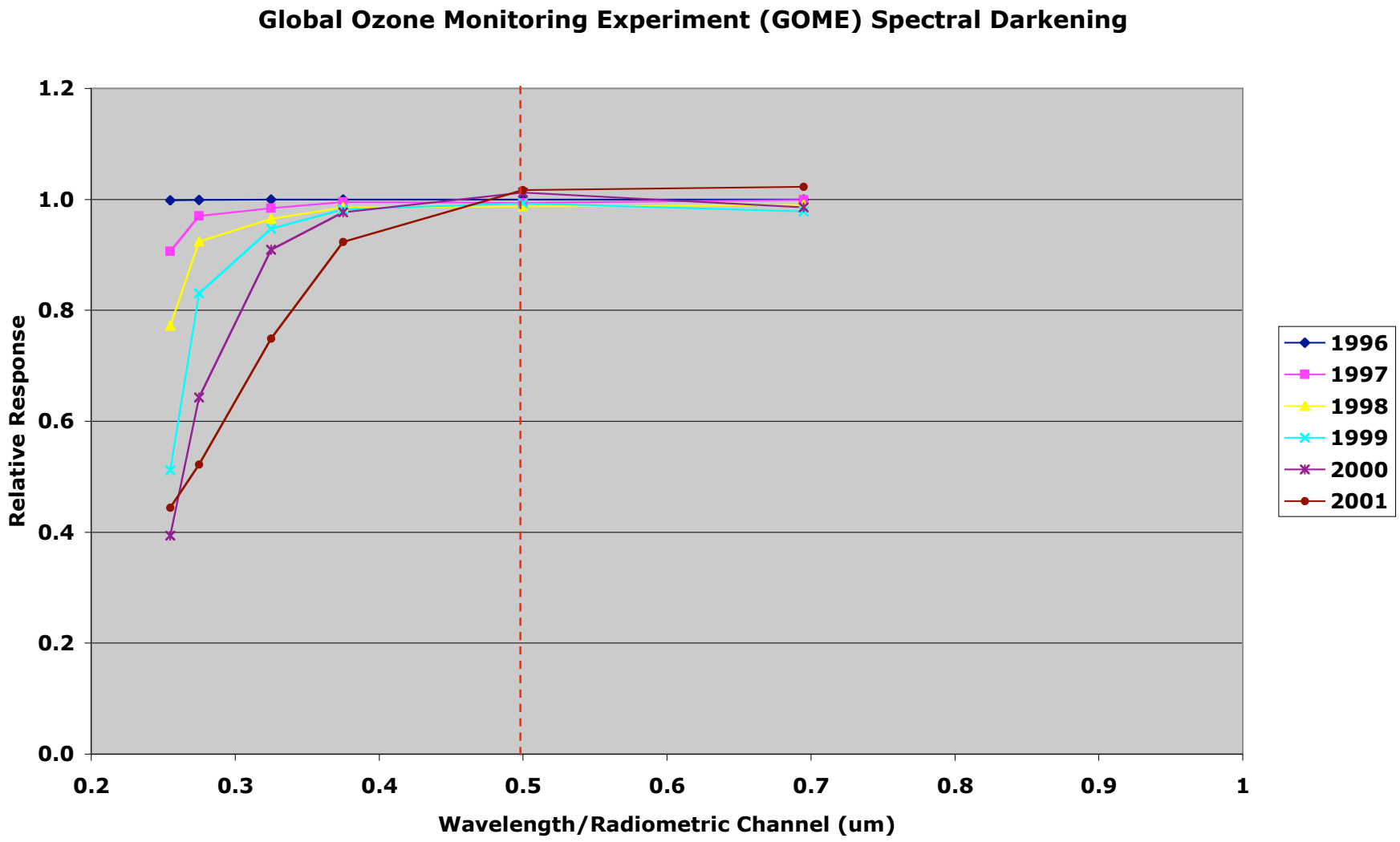
Comparison of DC704 Contamination Studies



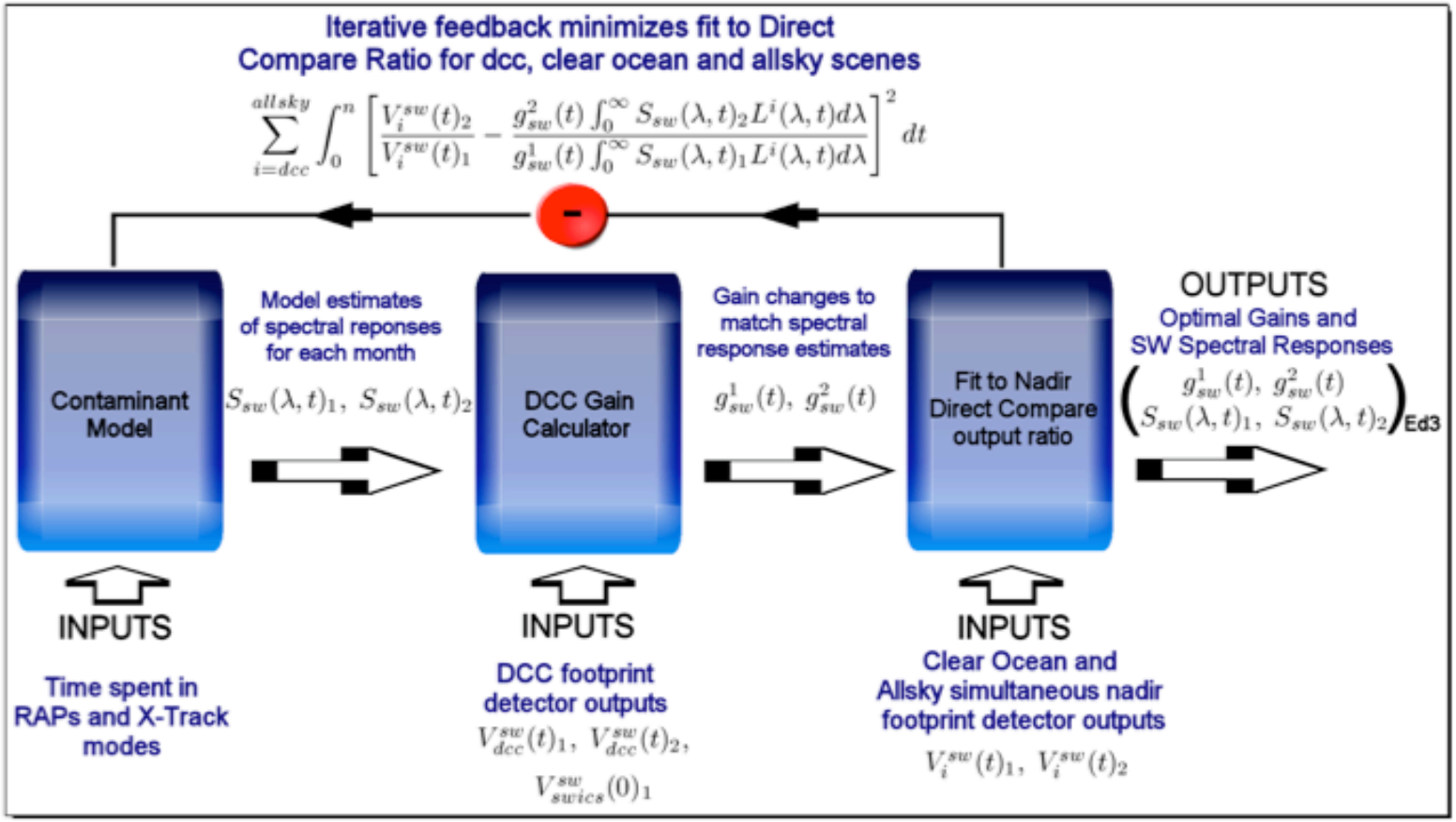


- Boeder's study suggests increased transmission above ~800 nm
- More consistent with Gain changes necessary in Ed3P modelling effort

Spectral Darkening on Similar Missions

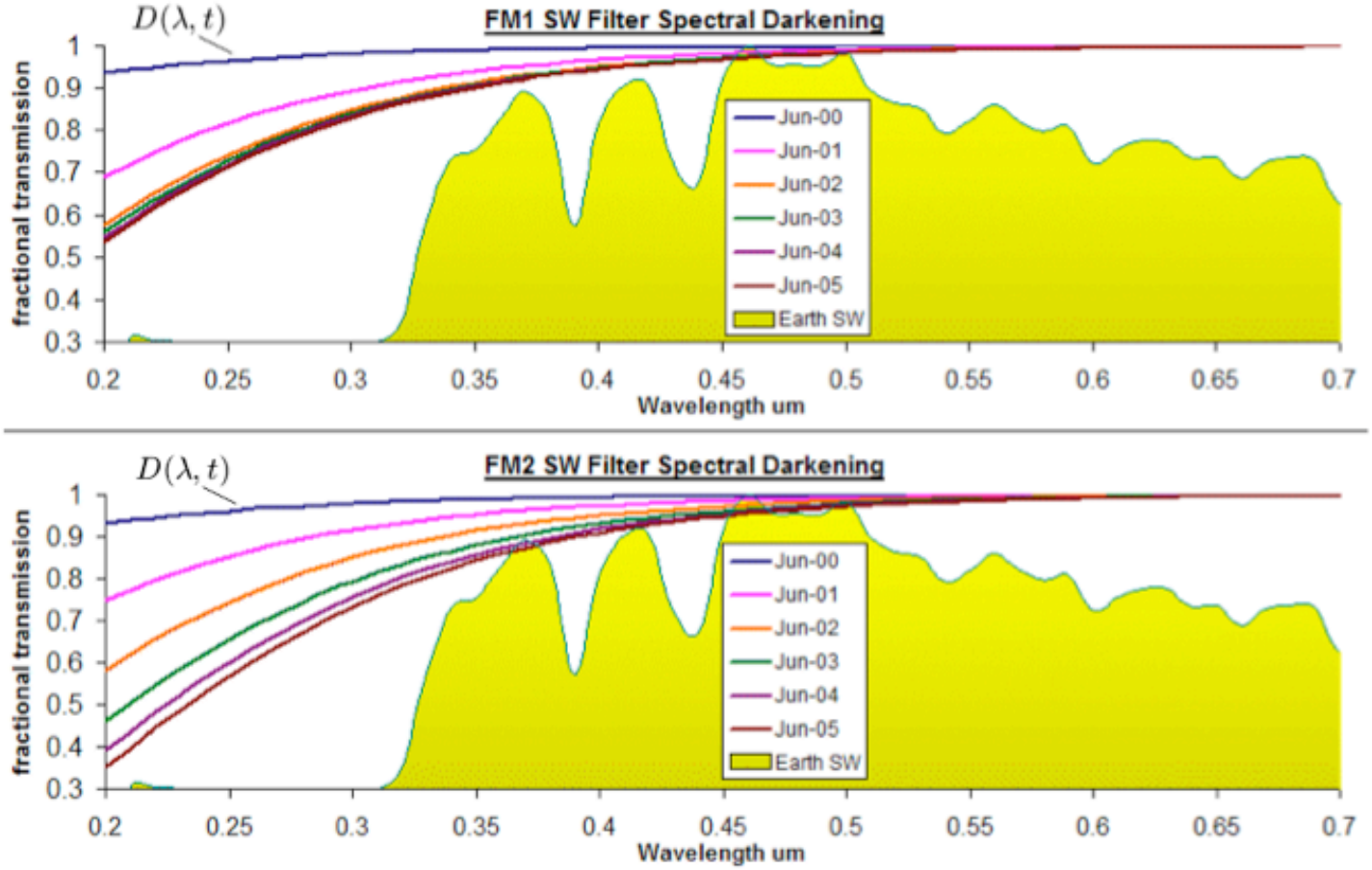


Edition3P SW Model Process



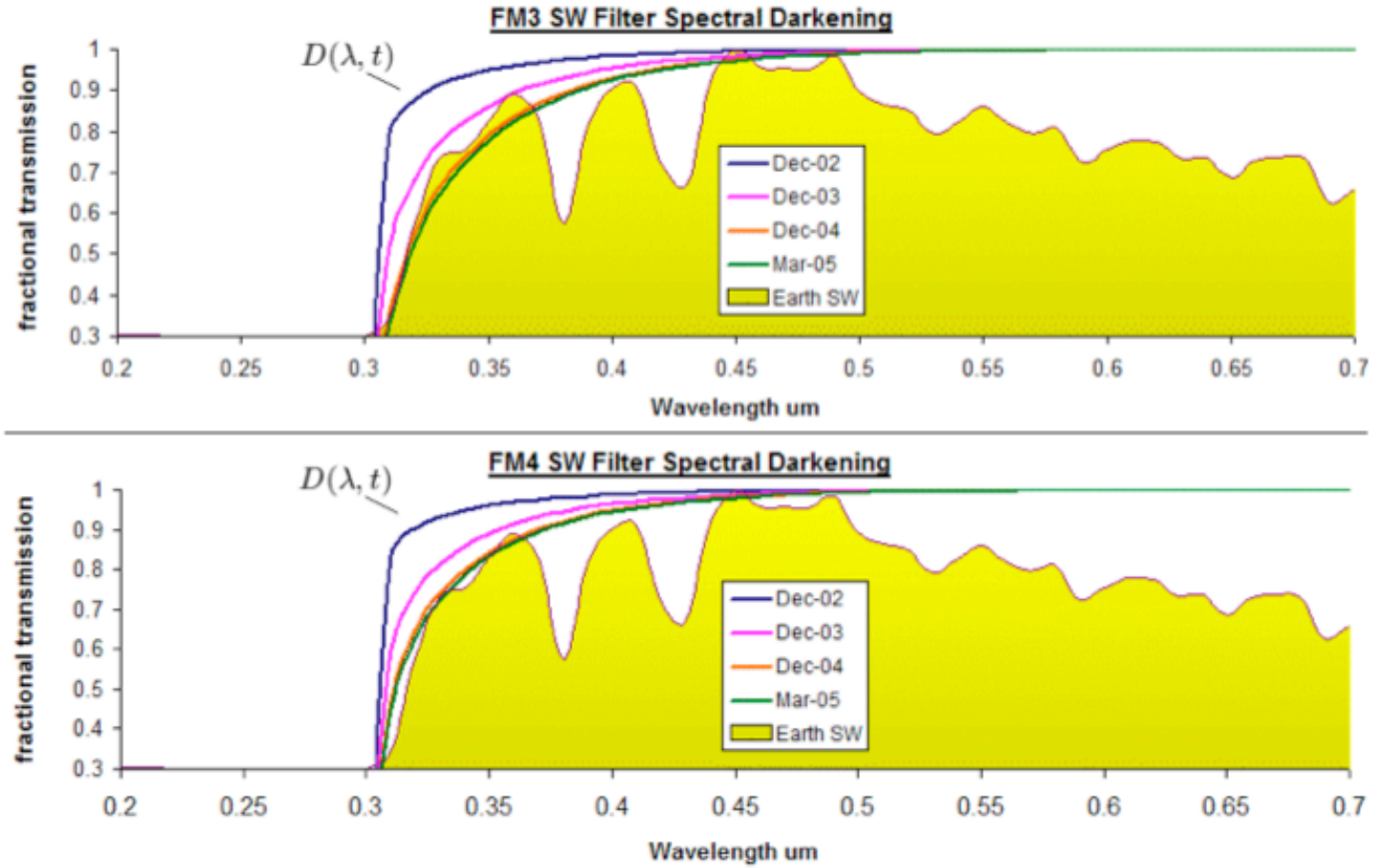
Edition3P SW Spectral Degradation

Terra

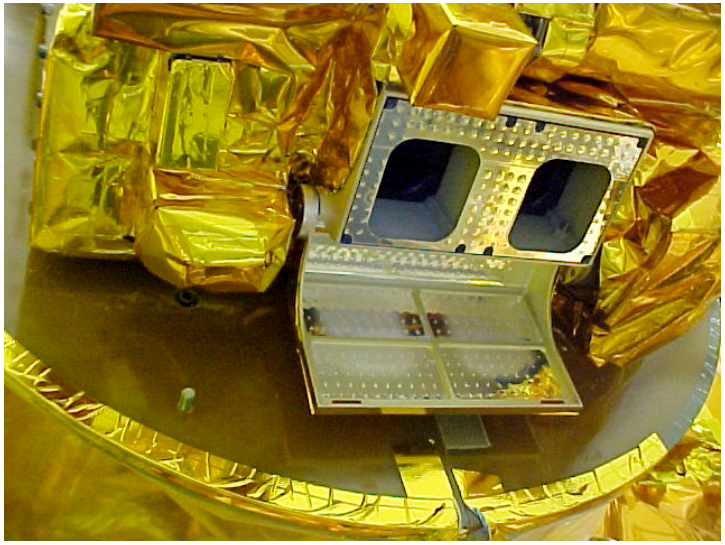


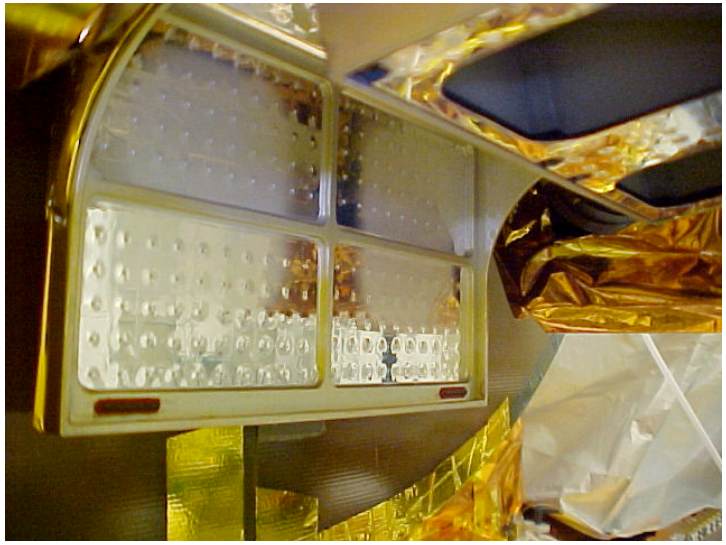
Edition3P SW Spectral Degradation

Aqua



Foggy Aqua FM-3 MAM Contamination Cover



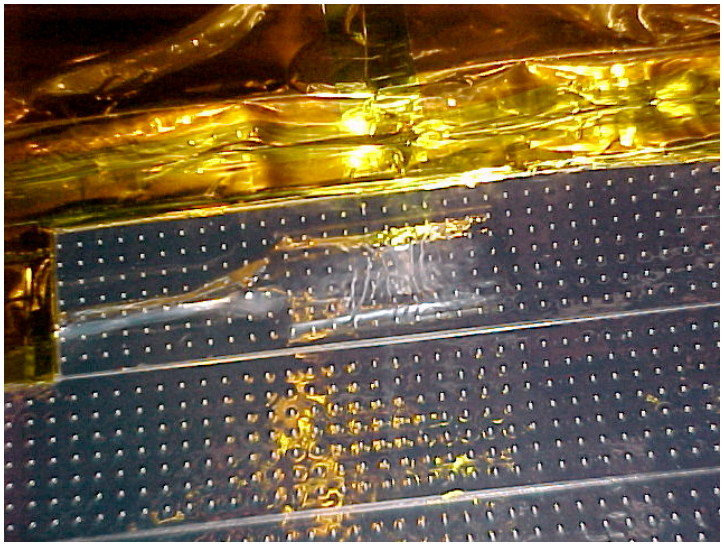


- Subsequent to spacecraft level thermal vacuum testing, a visual inspection of the FM-3 instrument revealed a ‘fog’ on the interior surface of the FM-3 MAM contamination cover.

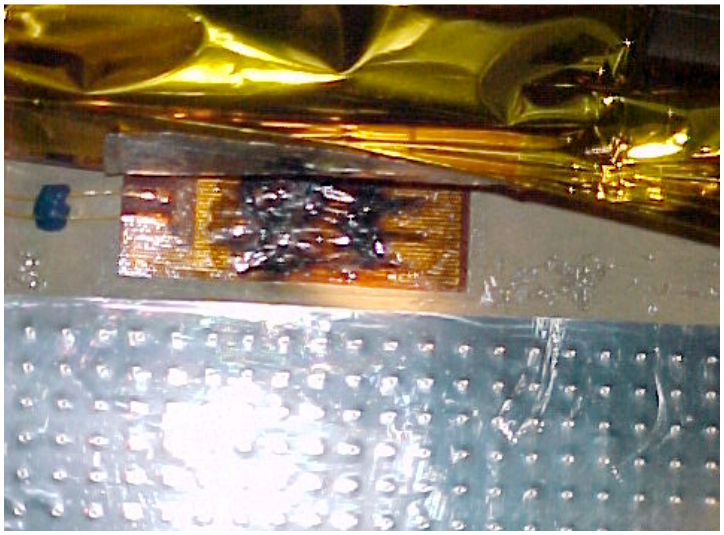
- Visual inspection of optics revealed no visible deposition.

- Testing yielded conflicting opinions of the material, most likely candidate was pennzane lubricant.

Burnt CERES Aqua Test Heaters

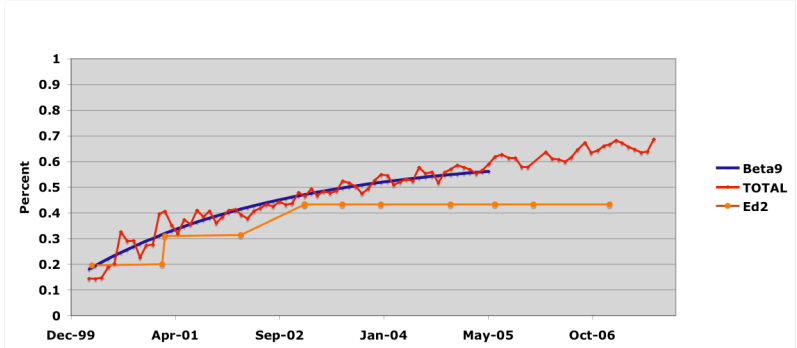


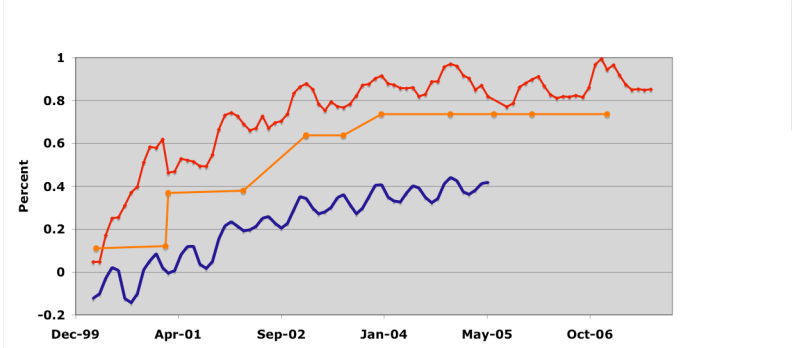
Prior to spacecraft level thermal vacuum testing, spacecraft personnel overloaded test-only heaters on the CERES Aqua instruments.

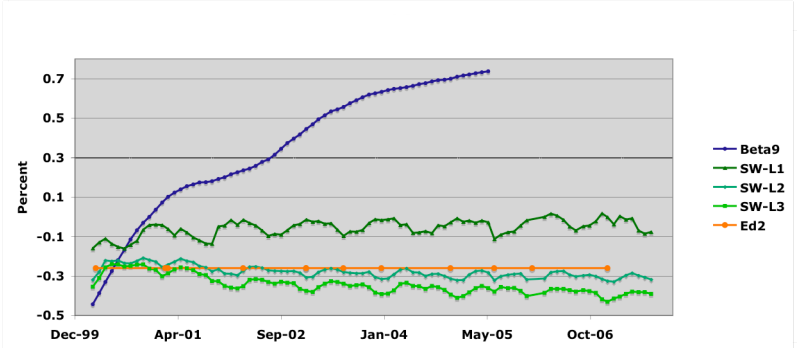


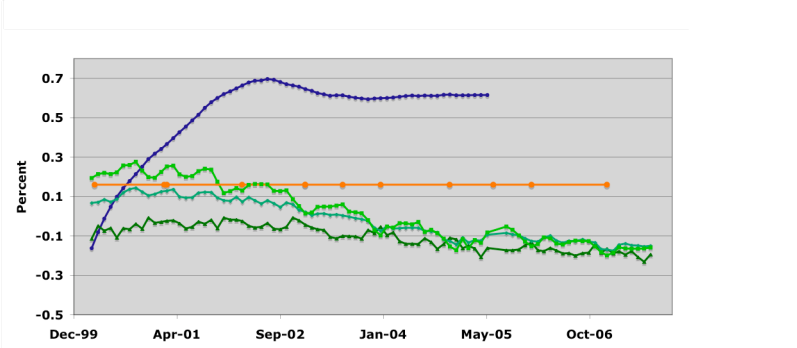
Heaters were visibly charred and destroyed. Location is external to optical chamber and under silver teflon radiators. Heaters were removed and area cleaned prior to thermal vac testing.

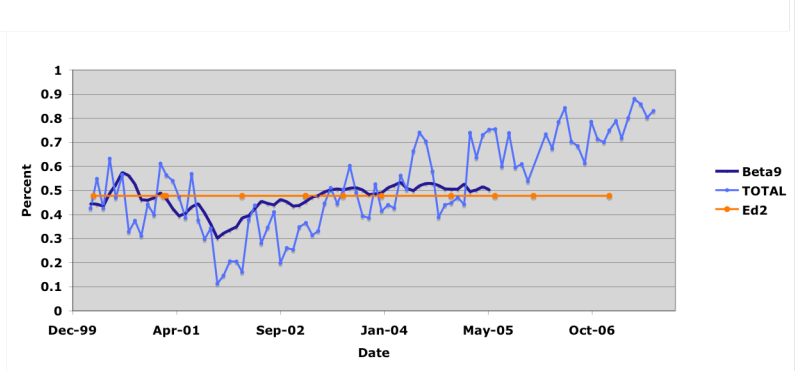
Ed3P Estimated Gain Trends - Terra

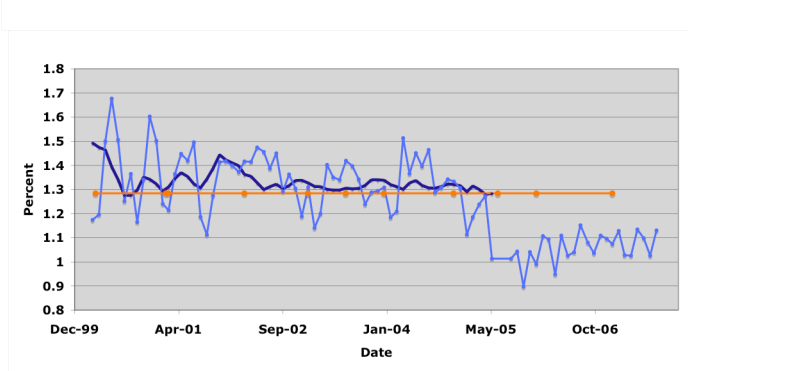






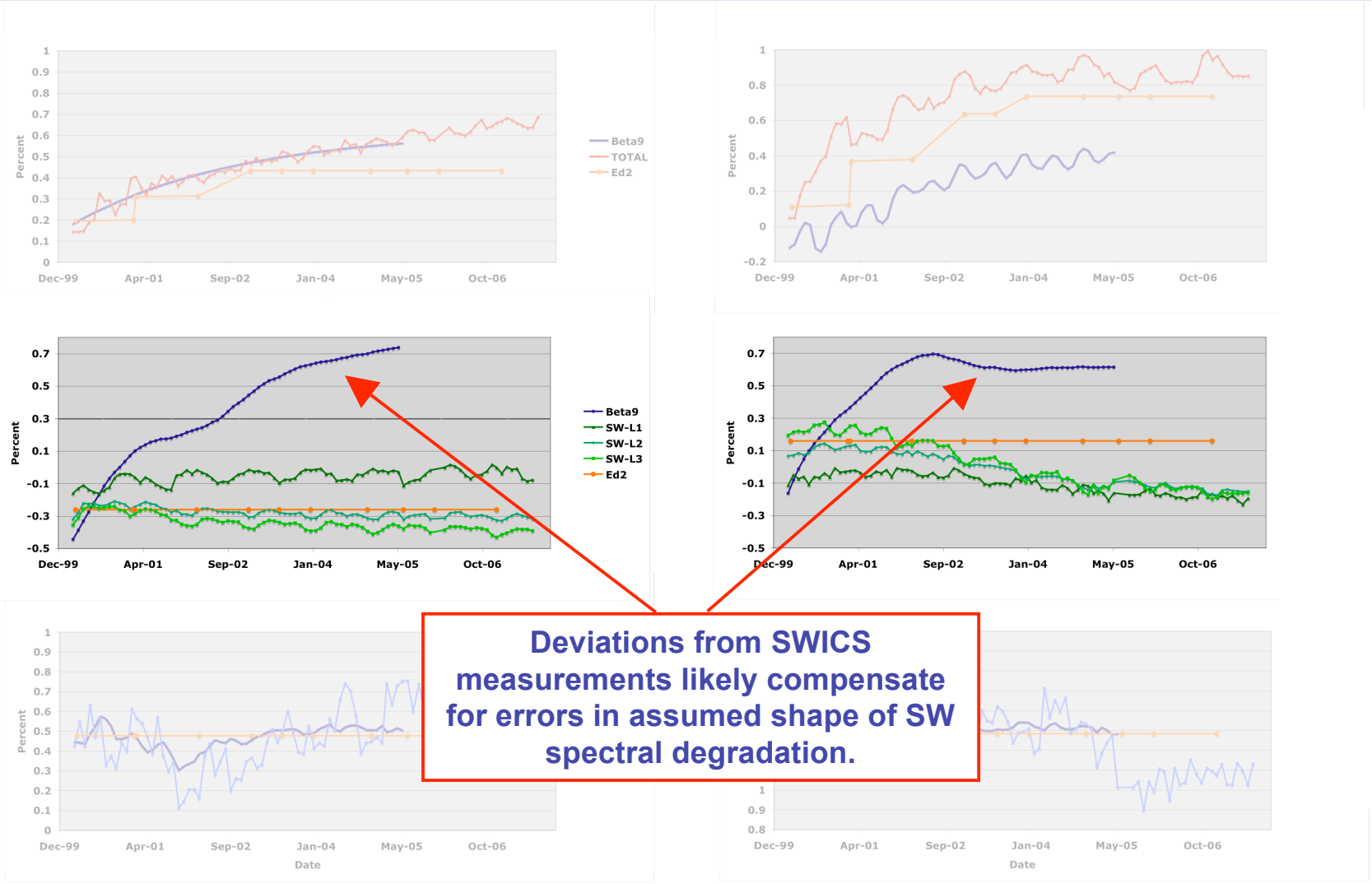






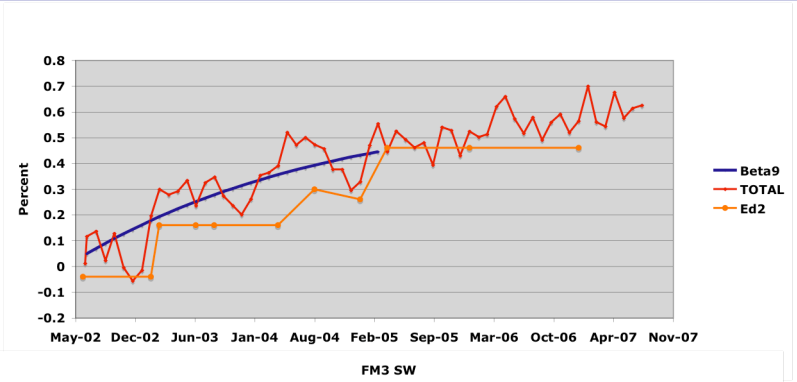
FM1 **FM2**

Ed3P Estimated Gain Trends - Terra



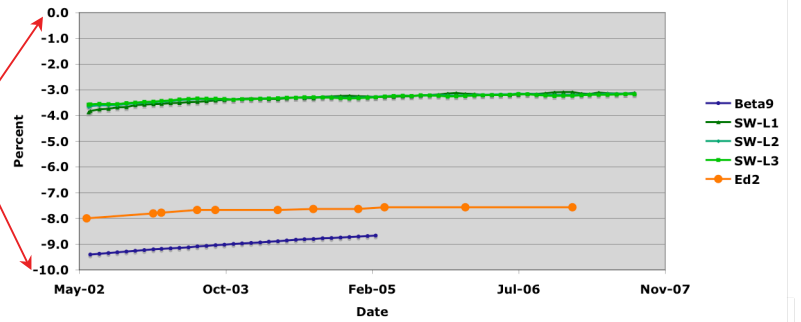
FM1 **FM2**

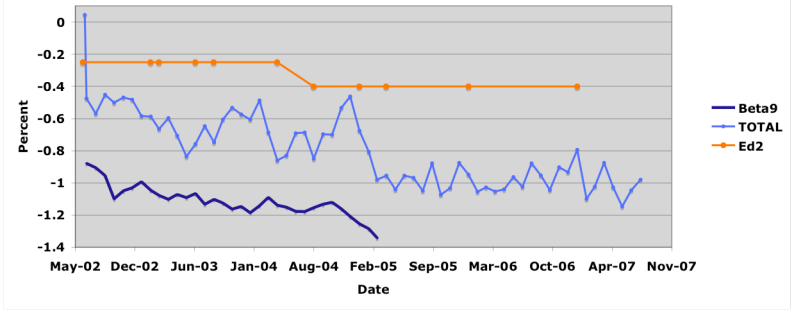
Ed3P Estimated Gain Trends - Aqua

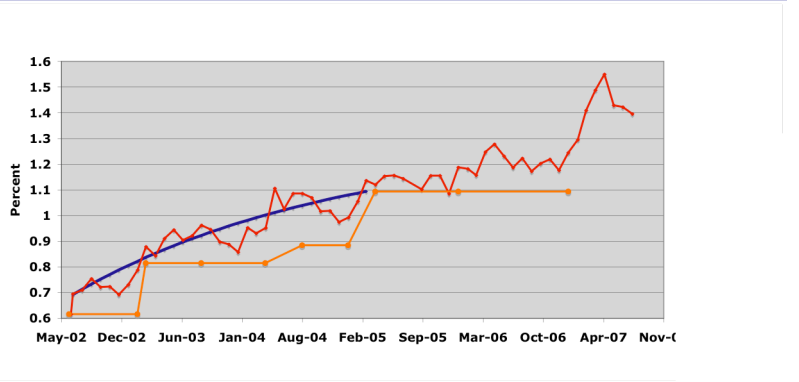


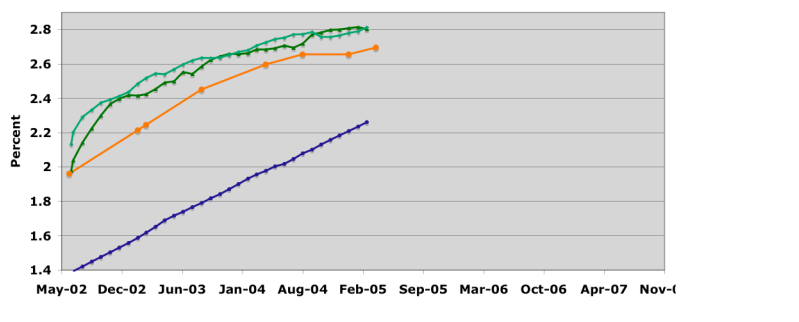
FM3 SW

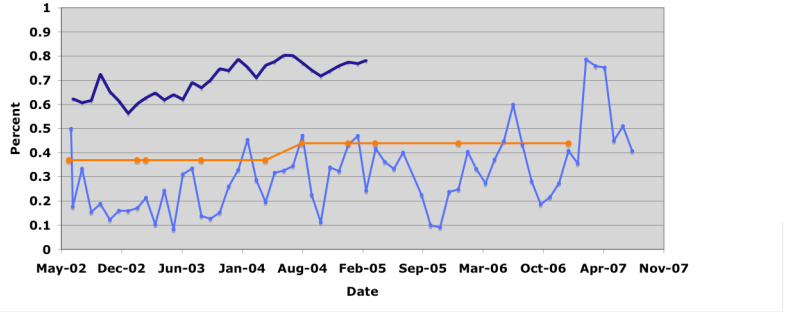
Note: Expanded Scale







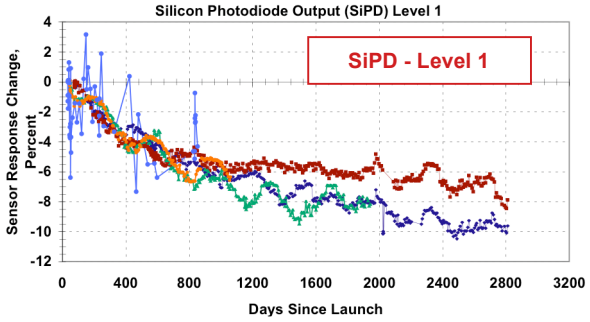


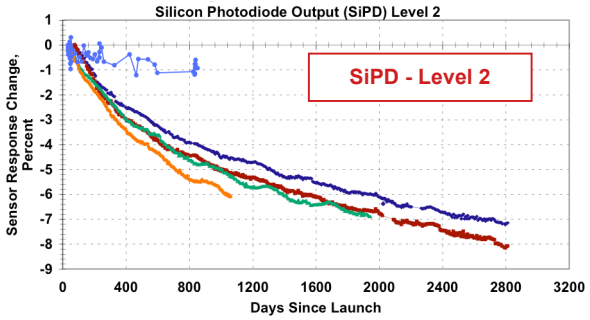


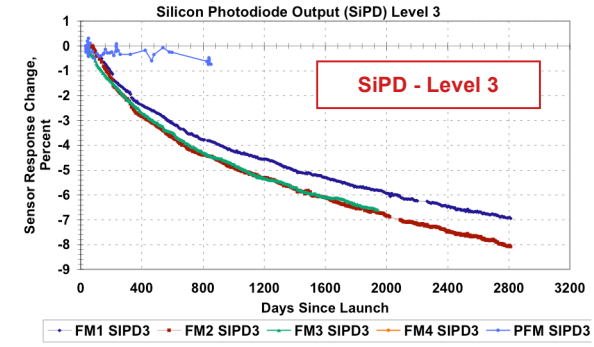
FM3 **FM4**

SiPD Monthly Average ICM Results

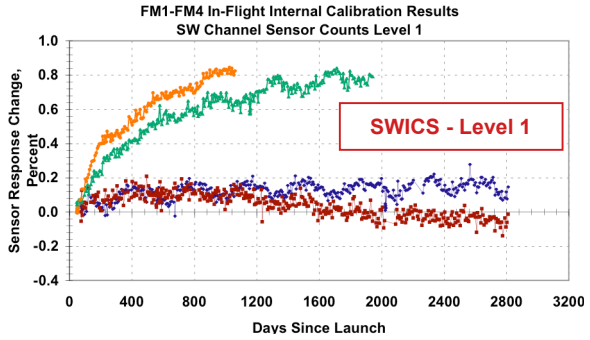
Stability Monitor

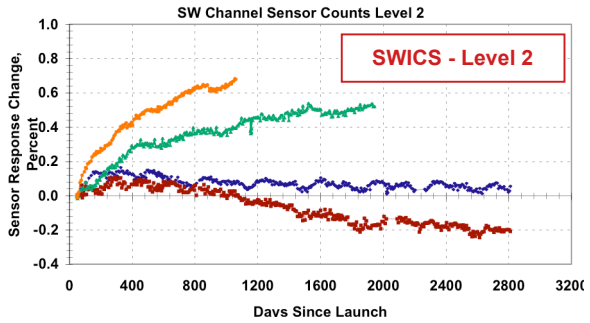


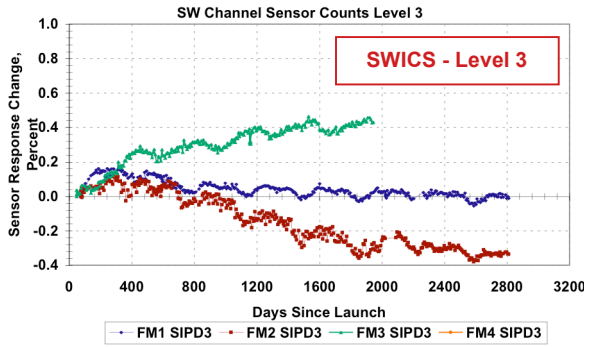




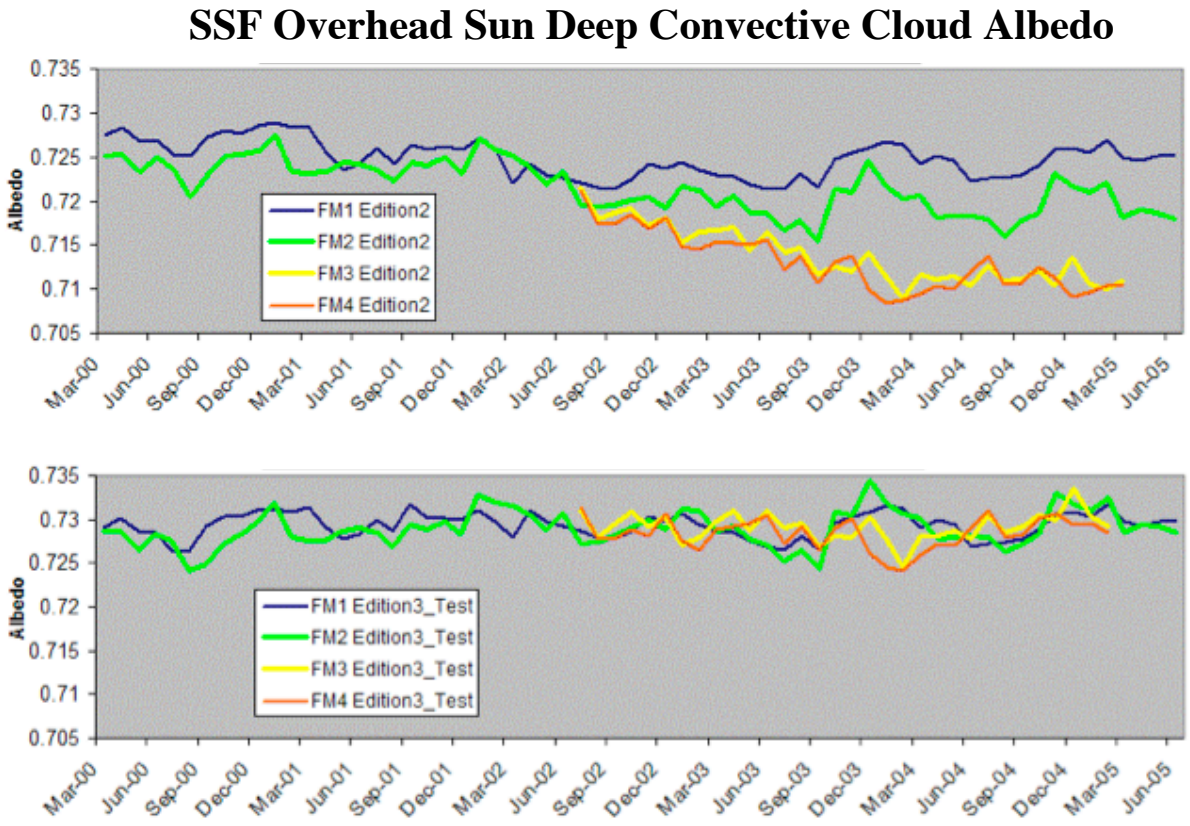
Lamps







Results: Deep Convective Cloud Albedo

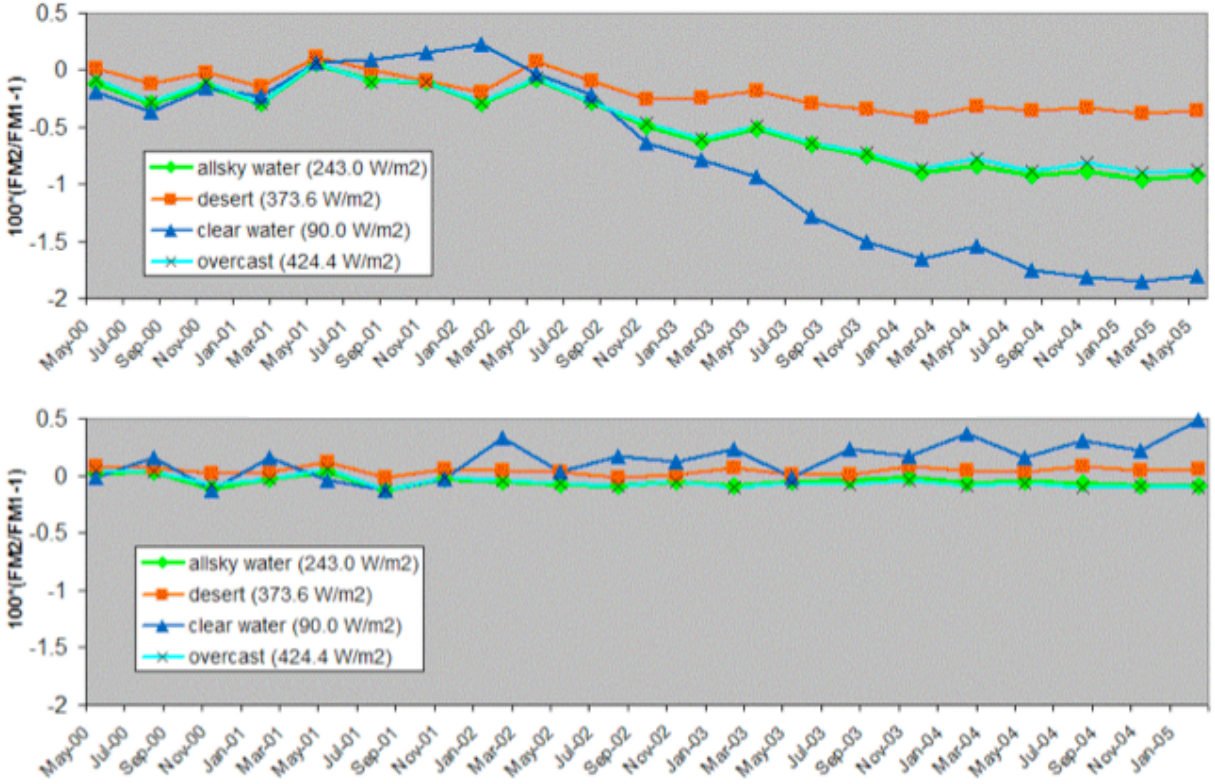


Edition 2

Edition 3P

Results: TOA SW Flux Direct Compare

Terra

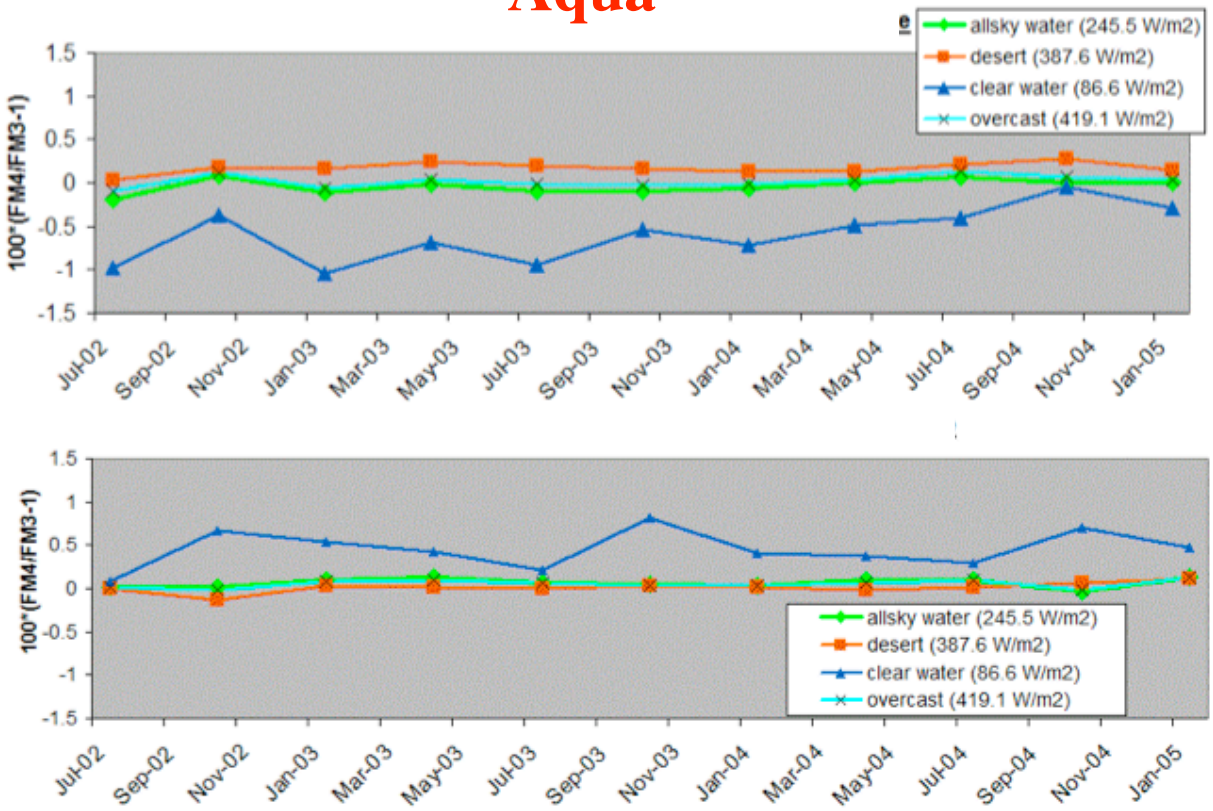


Edition 2

Edition 3P

Results: TOA SW Flux Direct Compare

Aqua



Edition 2

Edition 3P

SW Edition 3P Calibration

- Results -
FM1 TOA Flux Anomaly Trends

Methodology

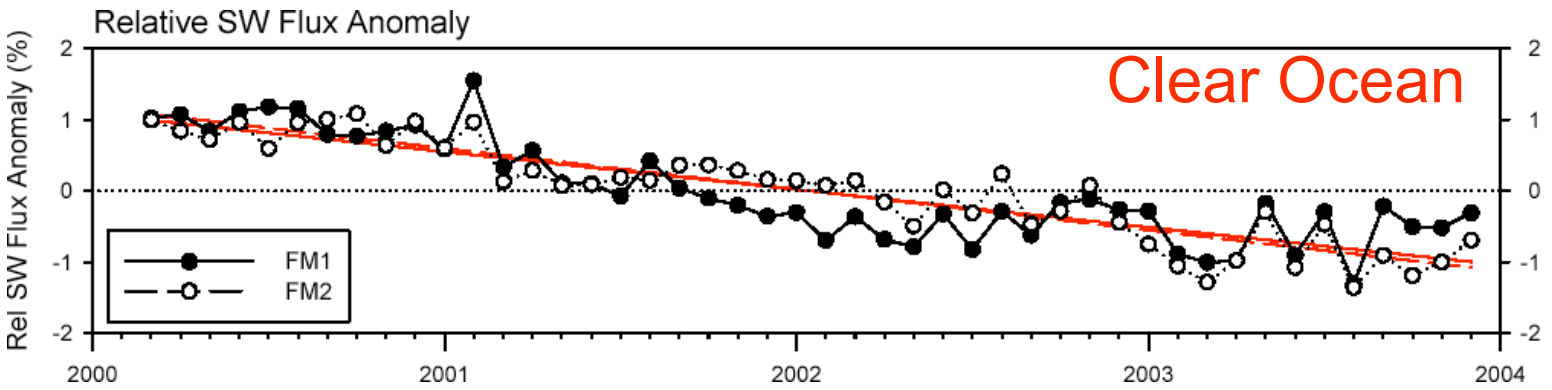
- Generate TOA fluxes {SW, LW (day), LW (night), WN (Day), WN (night)} using instrument group's recent FM1 instrument gains and spectral response functions for 70 months (March 00 - December 05).

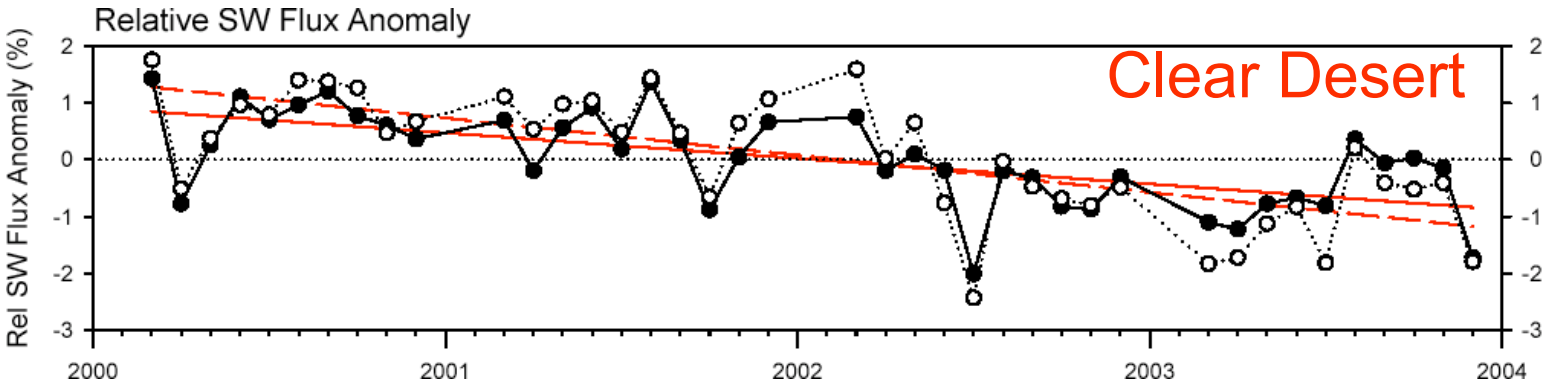
  Inputs: SSF Ed2 cloud properties; Ed1 Cal/Val ES8s; Ed3_beta7 gains & unfiltering coefficients; CERES ADMs; CERES directional models.

  Approach: Apply insturment gains; run unfiltering module; apply ADMs to determine TOA flux; convert SW TOA flux to 24-h average using CERES DMs.

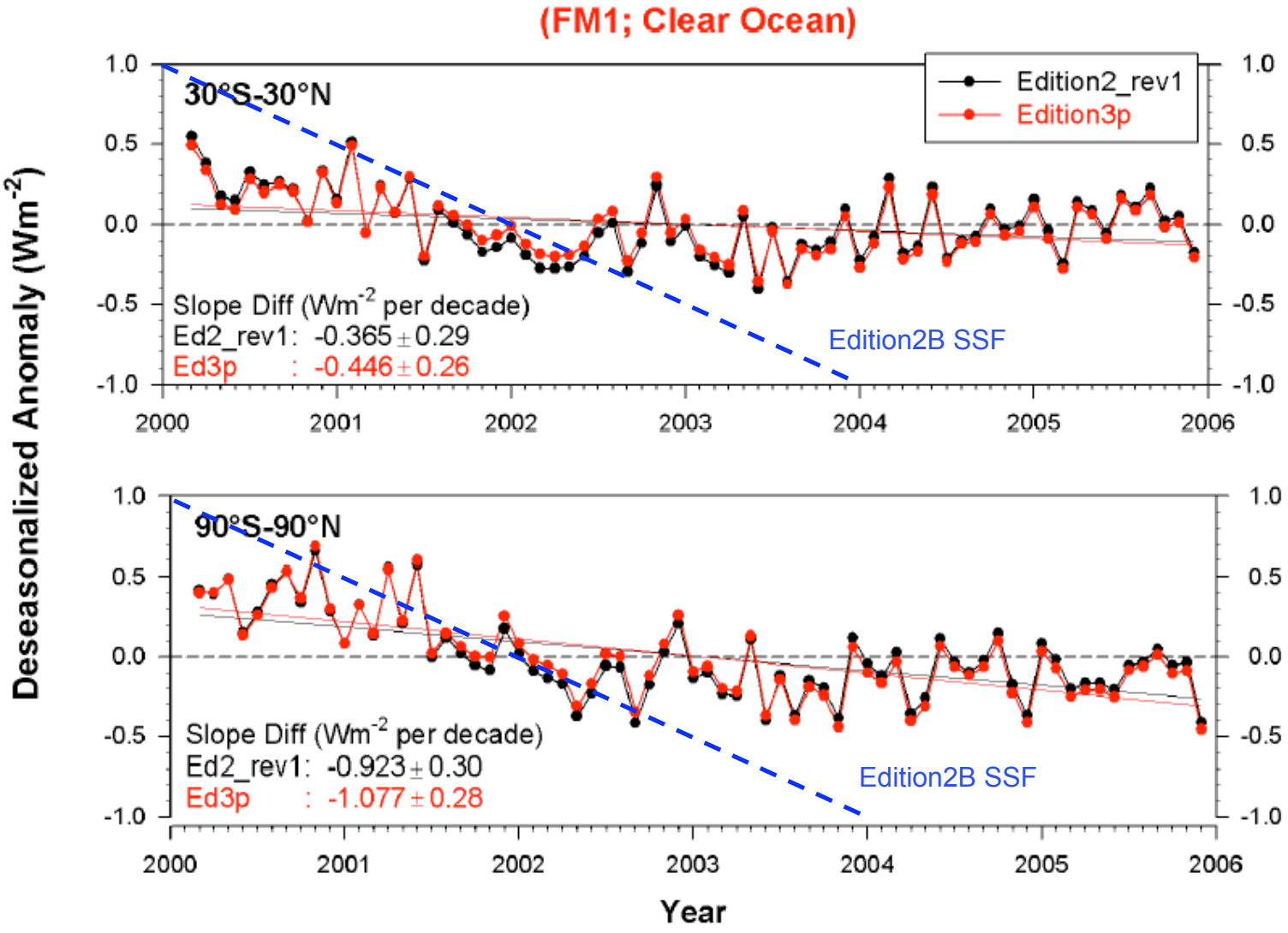
=> Idea is to produce 5 years of TOA fluxes that are very similar to what TISA would produce after running at LaRC ASDC.

CERES SSF Ed2B SW TOA Flux Anomaly

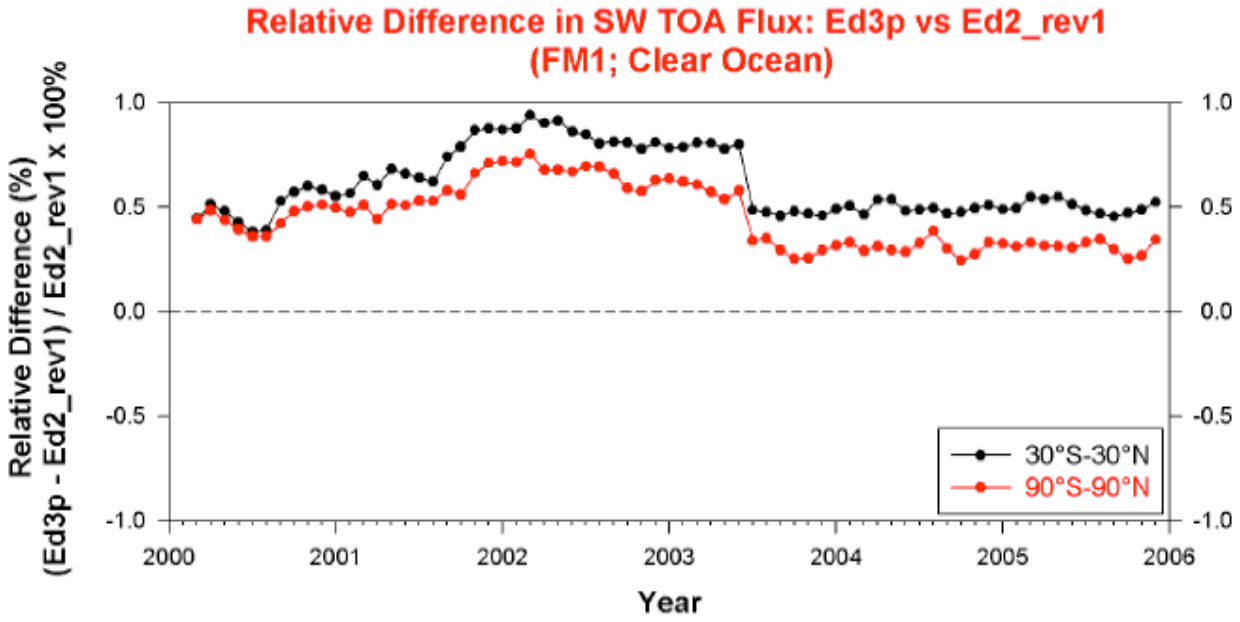




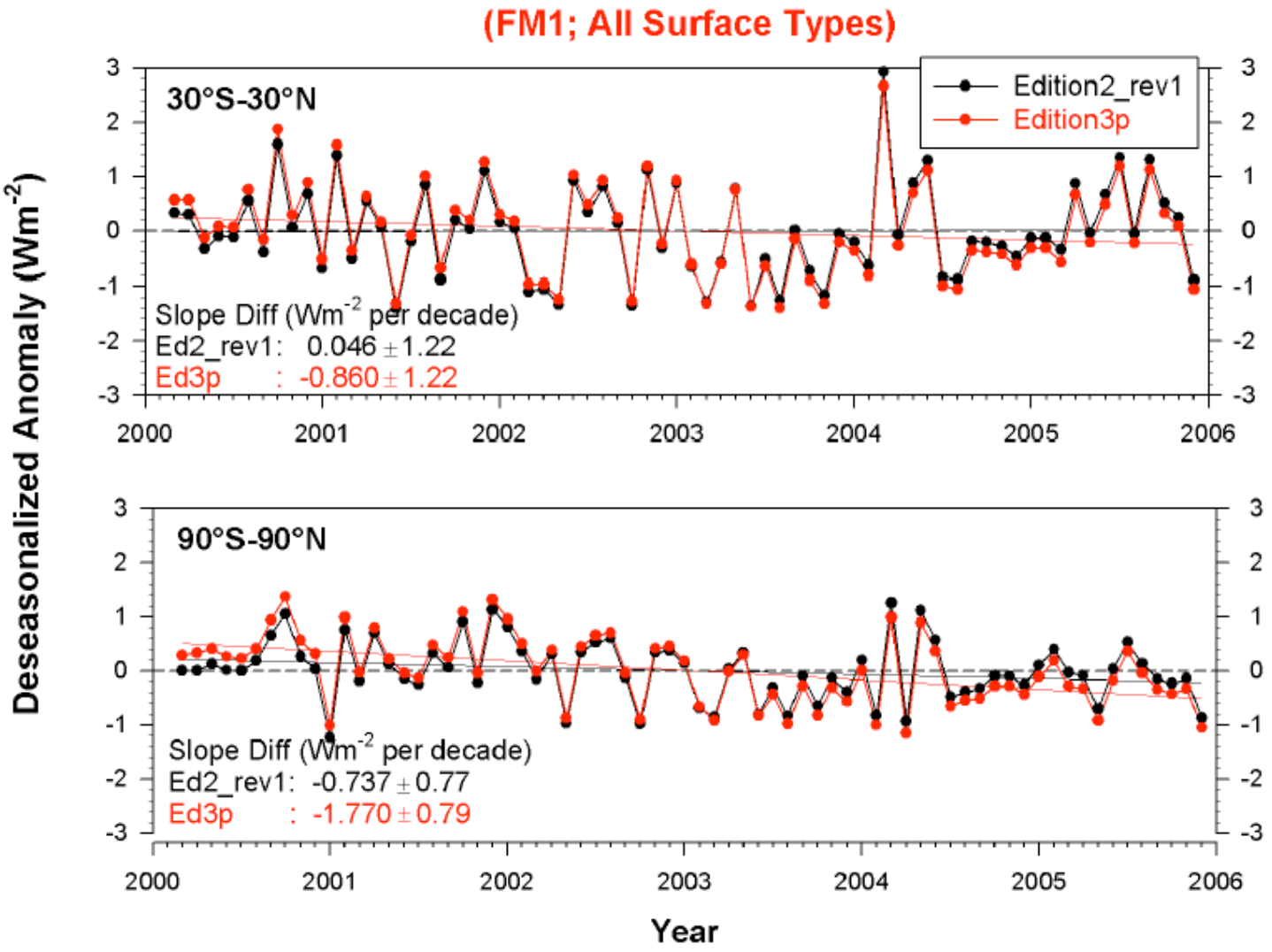
SW TOA Flux Anomalies : Clear Ocean



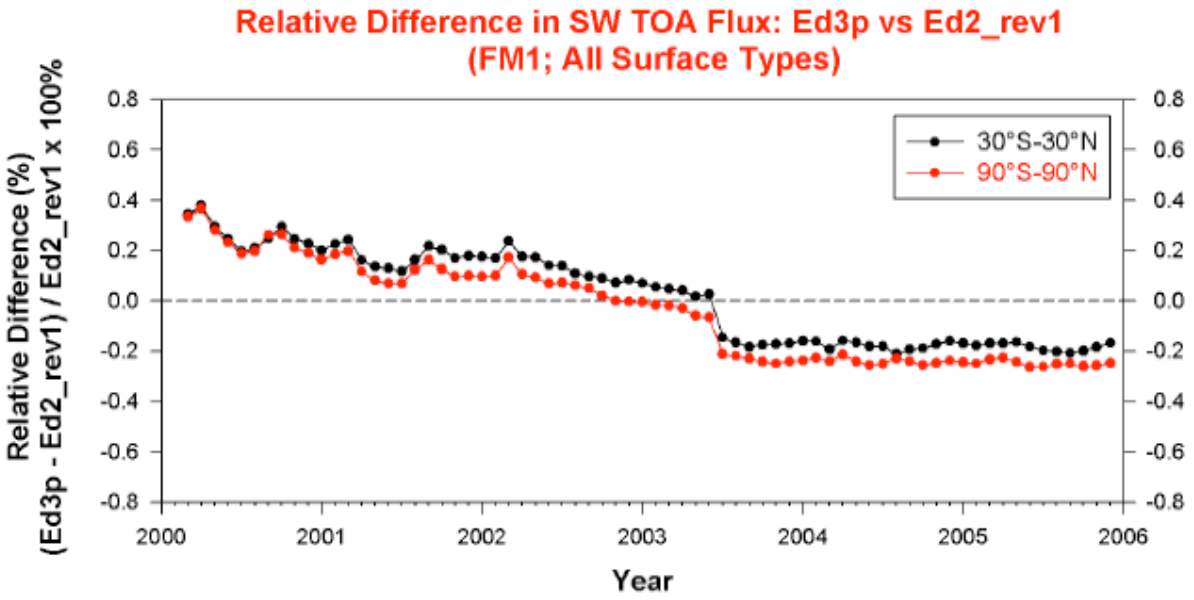
SW TOA Flux : Clear Ocean : Ed3P vs. Ed2_Rev1



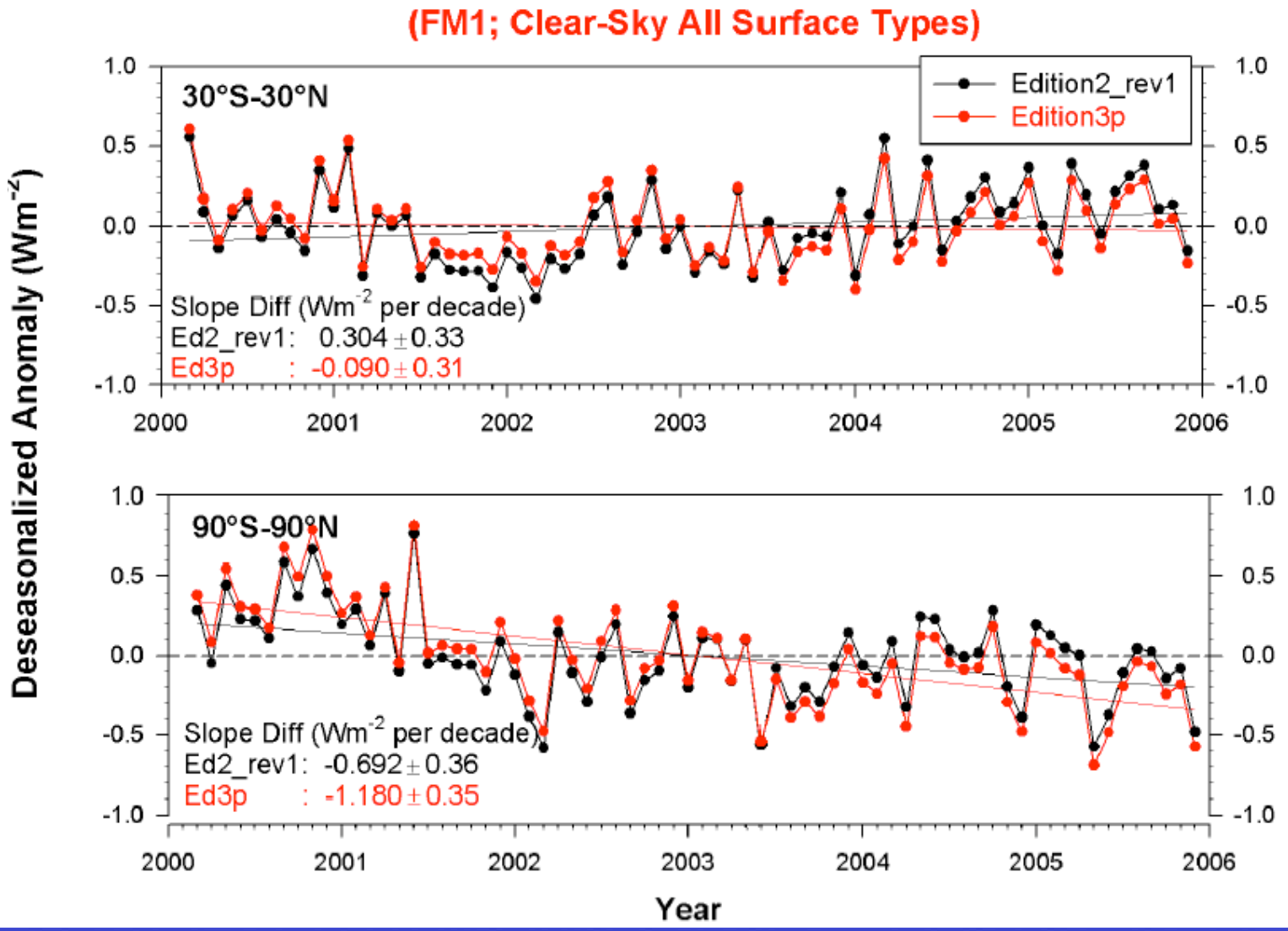
SW TOA Flux Anomalies : All Sky



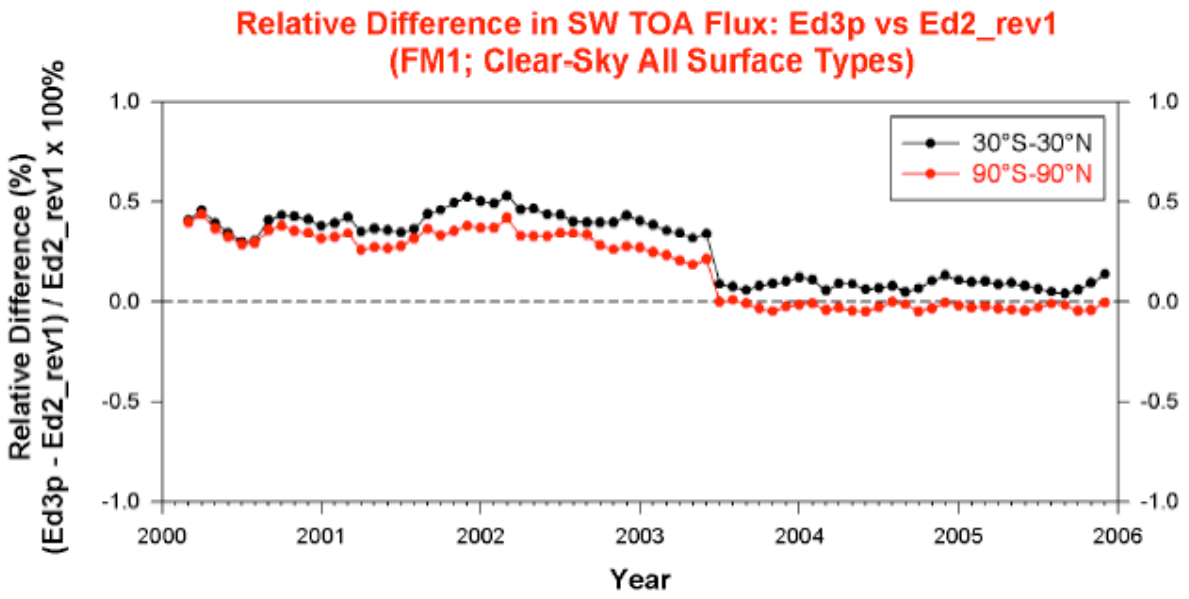
SW TOA Flux : All Sky : Ed3P vs. Ed2_Rev1



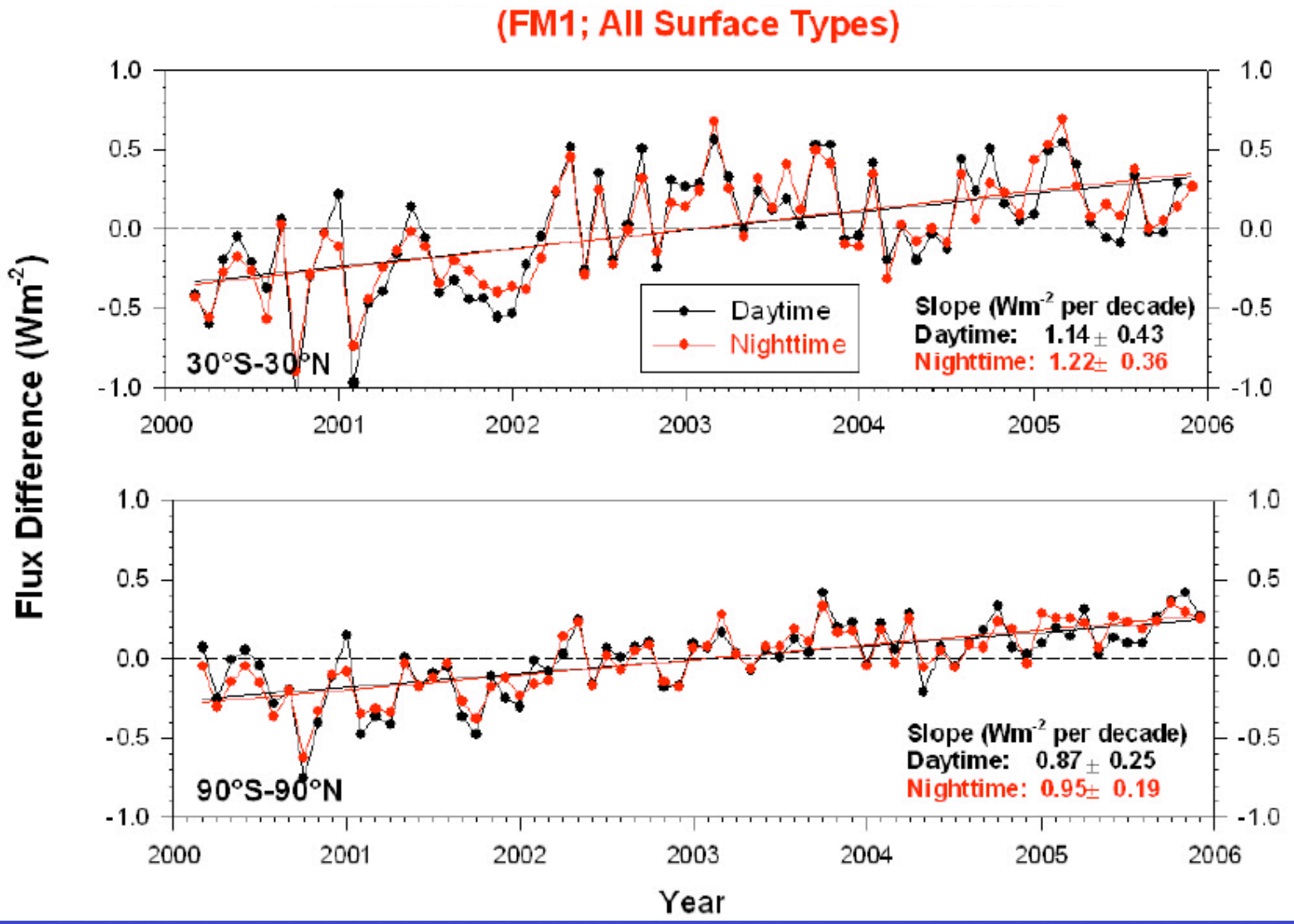
SW TOA Flux Anomalies : Clear Sky



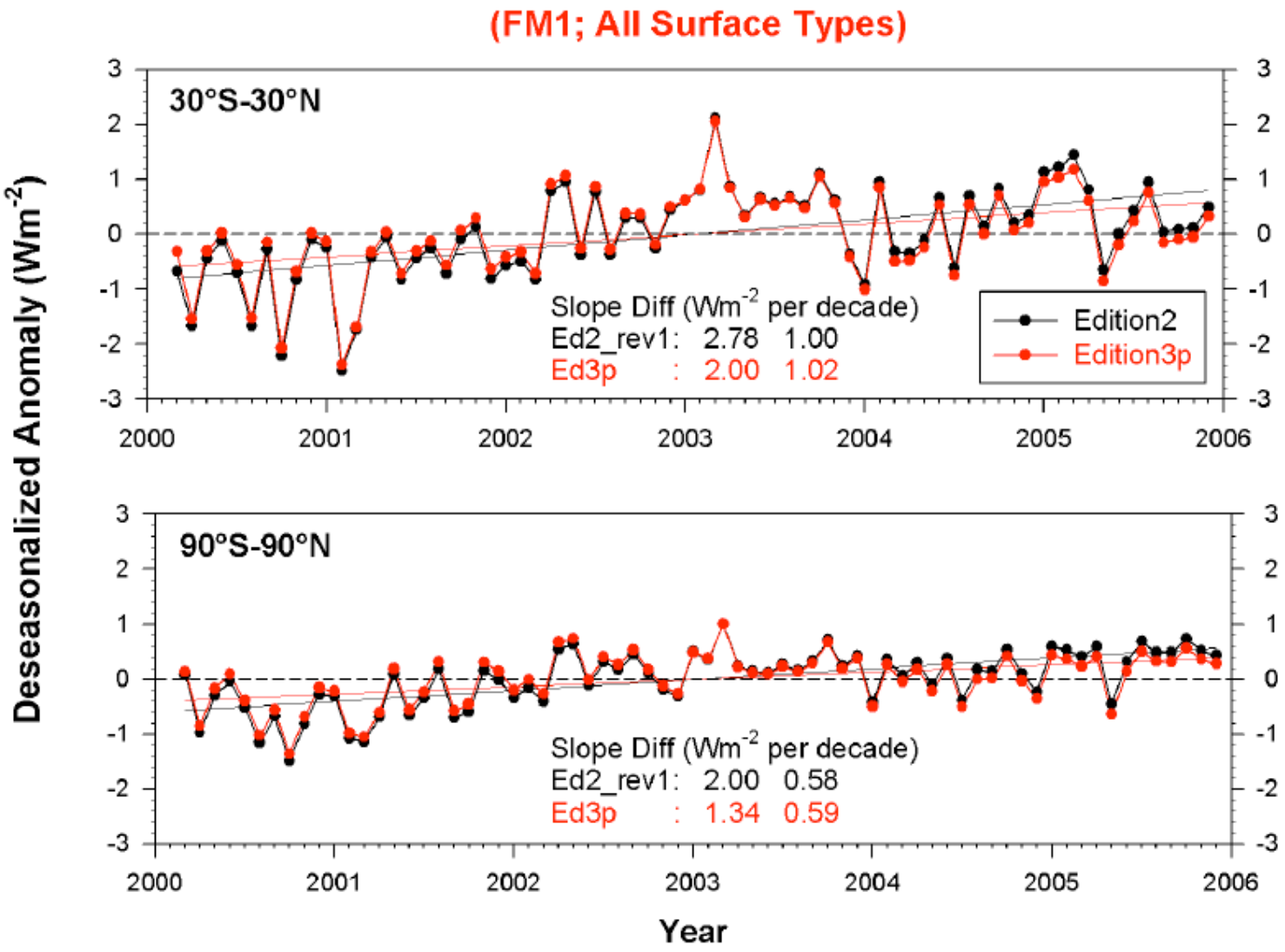
SW TOA Flux : Clear Sky : Ed3P vs. Ed2_Rev1



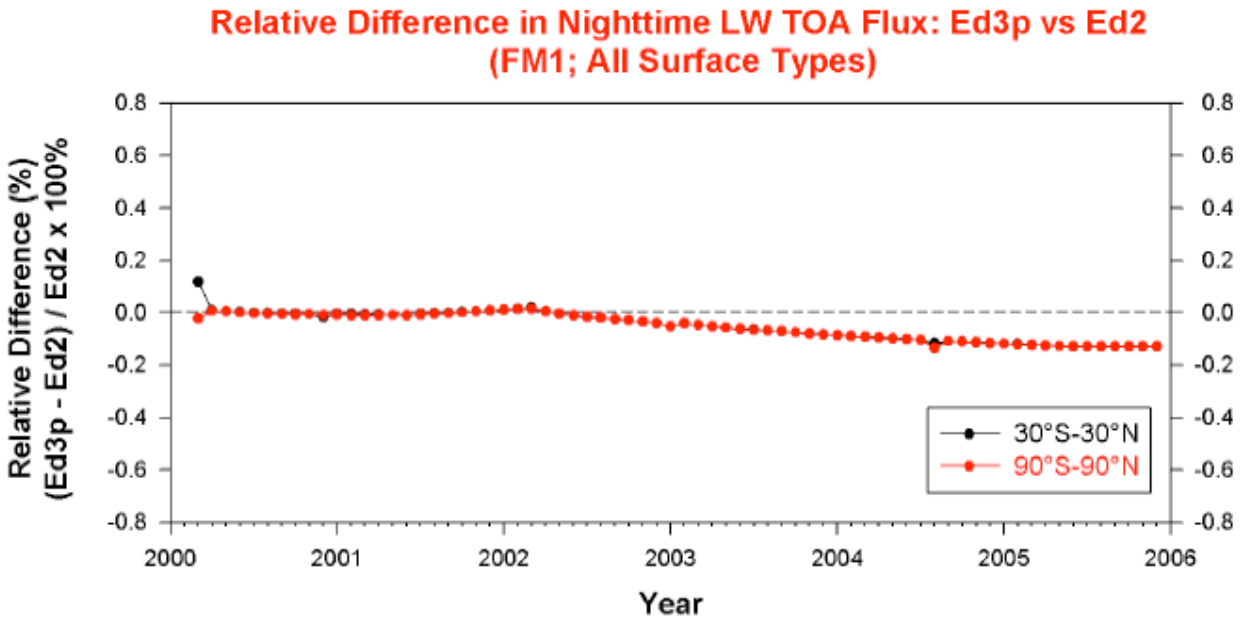
WN TOA Flux Anomalies : All Sky



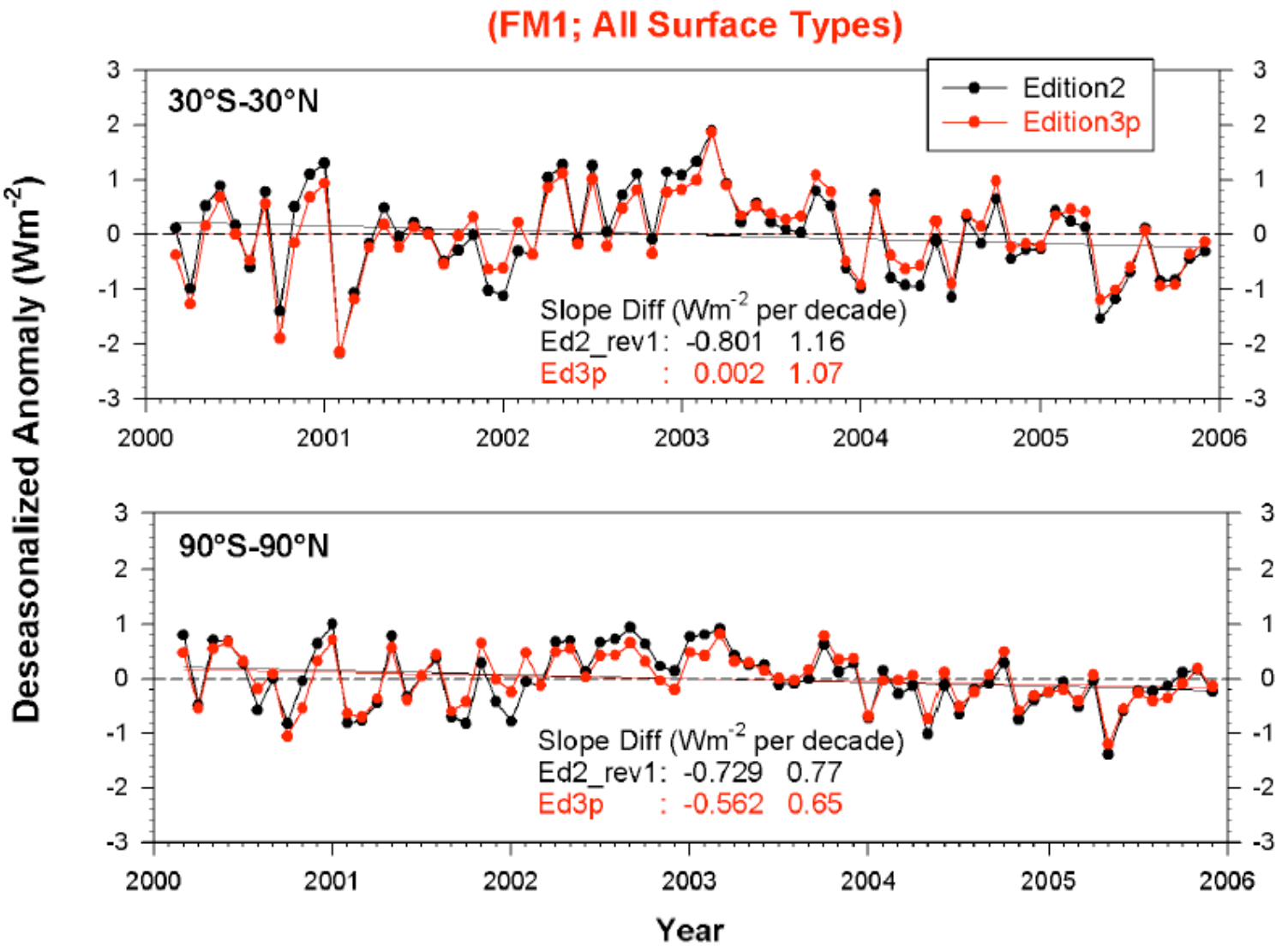
LW Nighttime TOA Flux Anomalies : All Sky



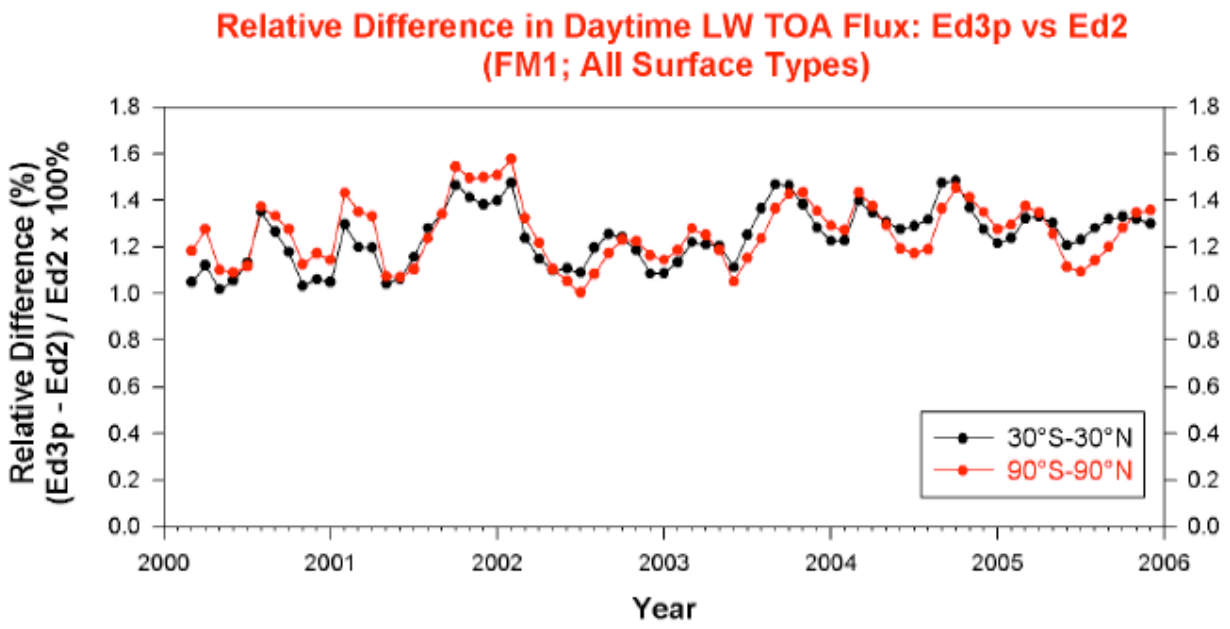
LW Night TOA Flux : All Sky : Ed3P vs. Ed2_Rev1



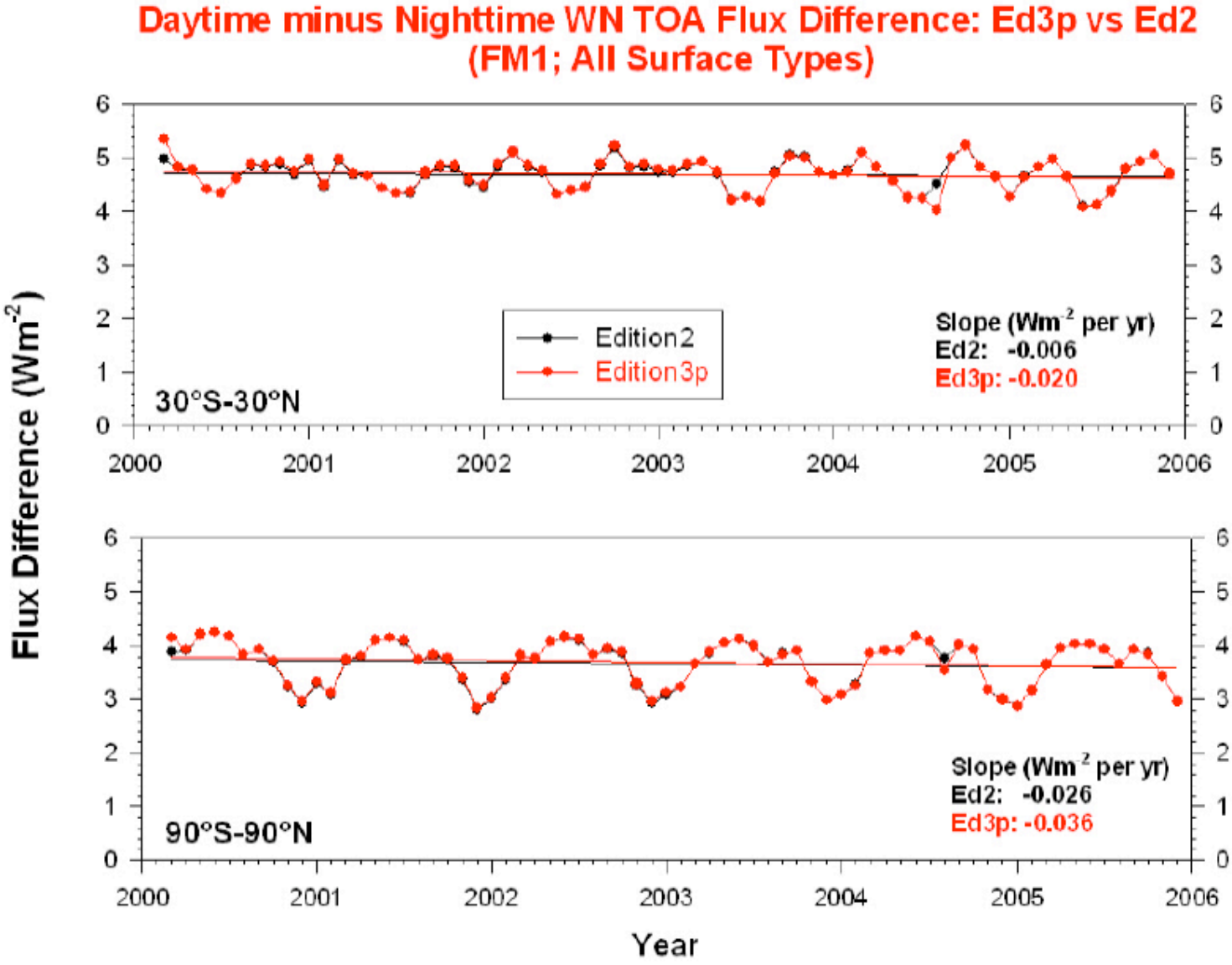
LW Daytime TOA Flux Anomalies : All Sky



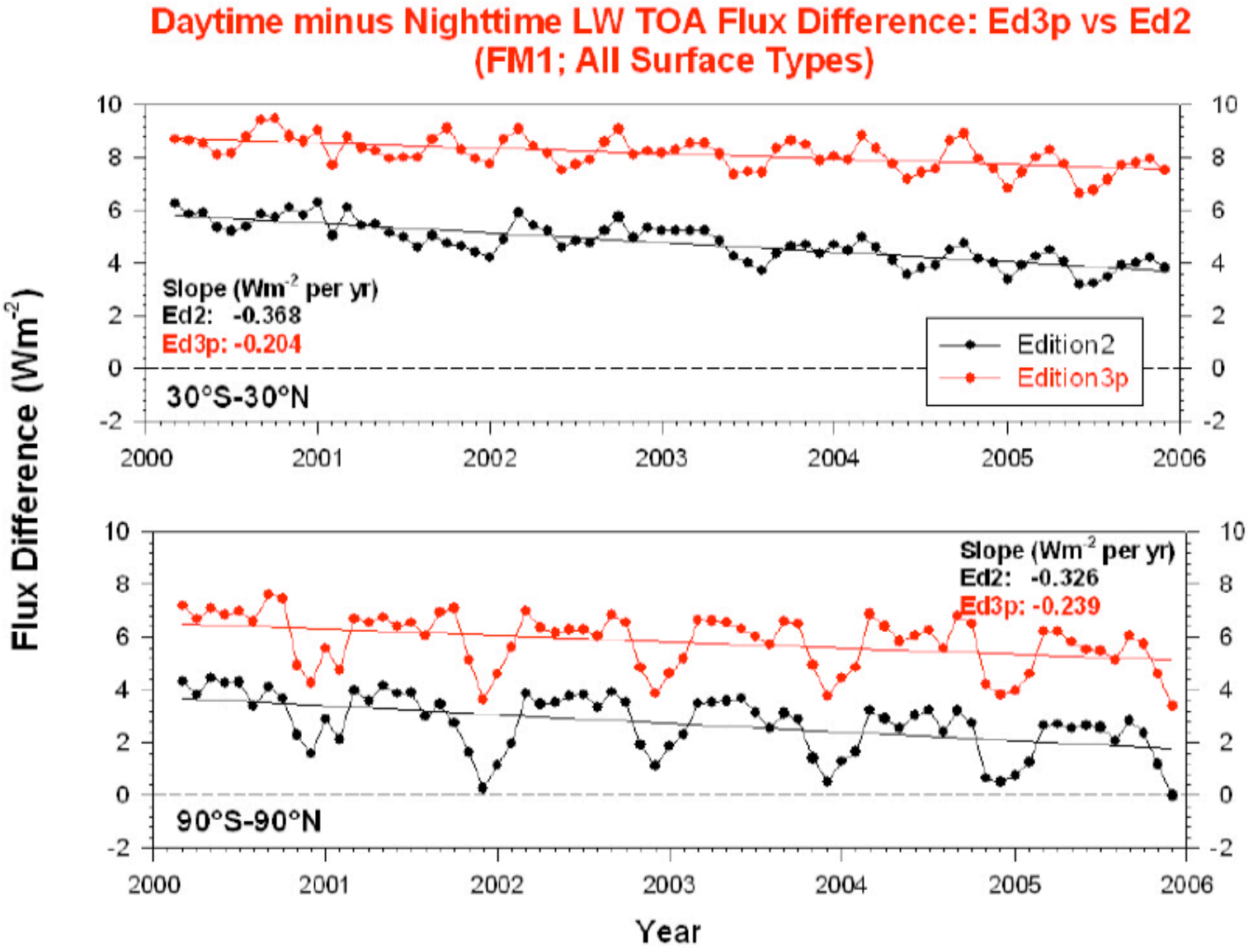
LW Day TOA Flux : All Sky : Ed3P vs. Ed2_Rev1



WN TOA Flux Anomalies : Day - Night : All Sky



LW TOA Flux Anomalies: Day - Night : All Sky



Summary

- Edition3P Results for FM1 are very encouraging

- Reduced scene type bias between instruments on the same spacecraft, placing them on the same radiometric scale.

- FM1 Ed3P Daytime LW, demonstrates anomolous trend relative to Nighttime LW and Day & Nighttime WN measurements.

- **Cause is residual error in the modeling of the SW/TOT channel**
- **Possibly different physics involved in contaminant deposition**

<u>Future Work</u>

- Revisit the assumption of the fundamental 'shape' of spectral changes.

- Complete the analysis of FM2 - FM4 Ed3P products.